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EVALUATING A TEACHER-PREPARED SET OF PROGRAMED INSTRUCTIONS FOR BASIC ELECTRICITY AS AN INTEGRAL PART OF THE INSTRUCTION IN A VOCATIONAL HIGH SCHOOL COURSE IN ELECTRICITY

by

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A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF EDUCATION

DEPARTMENT OF INDUSTRIAL AND VOCATIONAL EDUCATION

EDMONTON, ALBERTA

FALL, 1972

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Evaluating a Teacher-Prepared Set of Programed Instructions for Basic Electricity as an Integral Part of the Instruction in a Vocational High School Course in Electricity" submitted by Hans Weissenborn in partial fulfilment of the requirements for the degree of Master of Education.

ABSTRACT

The purpose of this study was to evaluate the effectiveness of a set of teacher-prepared programed instructional materials for basic electrical theory when used as an integral part of the instruction in a vocational high school course in electricity.

The programed material evaluated in this study was prepared by this investigator because commercially available programs did not seem suitable. The material consisted of twenty-two programed instructional units in electricity which were intended to replace the conventional lecture-discussion method traditionally used in teaching basic electrical theory. Each programed instructional unit was followed by a subtest. The subtests were included as part of the programed material to be evaluated. The programed material was designed to be used in conjunction with other student activities such as laboratory experiments, problem assignments, etc. In this study the experimental group used the programed material together with such other activities.

The study was carried out with students enrolled in the Electricity 12 course in a number of Alberta composite high schools.

The evaluation of the effectiveness of the programed material was done by measuring the achievement that could be directly attributed to the programed material and by comparing the achievement and retention of the experimental

group with that of a control group. In addition, the achievement and retention was specifically measured in the cognitive classifications of knowledge, comprehension, and application. The study also measured time and attitude.

The learning achievement that could be directly attributed to the programed material was evaluated in terms of the results of the twenty-two subtests which were written by each of the subjects in the experimental group immediately after completion of each programed unit. Since no comparative evaluation was possible, an absolute standard of 75/75 was arbitrarily selected. This standard required that 75% of the subjects completed 75% of the items on each subtest correctly. Six of the twenty-two subtests did not reach this standard, but for the total of all subtest items 92% of all subjects reached a score of 75% or better.

The statistical comparison indicated that the achievement as well as the retention of the experimental group was significantly higher than the achievement and retention of the control group. This higher achievement and retention was observed in each of the cognitive classifications of knowledge, comprehension, and application. In addition, the experimental group spent significantly less time in completing the programed material than the control group spent in conventional lecture-discussion presentation of electrical theory. The statistical analysis

further indicated that the experimental group had a significantly more positive attitude toward programed instruction than an unbiased population would have.

ACKNOWLEDGEMENTS

The writer wishes to acknowledge with sincere appreciation the cooperation and assistance received from those who aided in the preparation, research, and completion of this study.

Appreciation and thanks are expressed to those teachers of vocational electricity courses who assisted in the development of the programed instructional material and in the validation of the test instruments. Particular thanks are due to Mr. F. Armstrong, Mr. R. A. Cooper, Mr. J. M. Dingman, Mr. M. Grant, Mr. K. W. King, and Mr. D. Mighton who spent considerable extra time and effort as the teachers of the control group.

The writer is indebted to Professor M. W. Petruk, for his extensive assistance and his helpful criticism as the thesis supervisor. Thanks are also due to the other members of the committee, Dr. T. O. Maguire and Professor D. W. Manuel, for their helpful suggestions.

My wife, Inge, was, as usual, understanding and helpful throughout the years of preparation for and completion of this study.

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CHAPTER 1

THE PROBLEM

Introduction

Programed instruction can have several advantages when the right program is properly used. Such advantages include individualization of instruction and freeing the teacher from the more routine tasks of instruction, thus allowing more personal student contact. However, if a poor program is used, or if a good program is used in the wrong situation, these advantages may be offset by lower learning achievement, less retention, less transfer of learning, more student time required, and a negative student attitude toward this type of instruction.

How does a teacher know whether a set of programed instructions is suitable for his purpose and effective in reaching the objectives that he has set for his class? He must first find a program whose learning objectives coincide with the learning objectives that were selected for his class. These objectives include the subject matter to be covered, the depth to which the various subject matter concepts are to be learned, the emphasis that is placed on attainment of facts, on understanding of concepts, or on transfer of learning. The program must be suitable for practical adoption in the class. If a program that meets all these demands can not be found, the teacher may consider preparing his own program for the course. Whether

the teacher uses a program prepared by others or his own program, he must obtain evidence that the program is at least as effective as the usual method of instruction. Only then can he make an objective decision whether to use this program or not.

The programed instructional material evaluated in this study was developed by this investigator after it was found that commercially available programs for basic electrical theory were not suitable in one or more of the aspects mentioned in the preceding paragraph.

The programed material was basically of the linear type. The development extended over a period of five years and included developmental testing and resulting revisions. The content was basic direct current theory as it is typically taught in introductory courses in electricity. The content coincided with that outlined in the curriculum guide for the Electricity 12 course for vocational high schools in Alberta (Dept. of Ed., 1969). The subtests that follow each programed instructional unit were considered part of the programed instructional material for the purpose of this study.

The programed material was not intended to teach complete mastery of each concept of each student. The investigator's previous experience indicated that such an attempt would overtax the motivation of most students enrolled in this course. This contention is shared by

several other researchers (See Review of the Literature, p. 23). The programed material was intended to replace the conventional lecture-discussion presentation, which by its very nature demands that students must progress in a lock-step manner through the learning of these concepts.

The programed instructional material consisted of twenty-two units. Each unit covered one, or a small number of related, concepts of basic electrical theory. Each unit was designed to take about one hour for the average student to work through. Each programed unit was followed by a subtest which was completed by each individual student as soon as he was finished with the preceding programed unit. Each individual student then went on with experiments, text book references, and problem assignments that related directly to the topic covered in the preceding programed unit. Some demonstrations were shown to the whole class or to a smaller group of students when they had completed the concept to be demonstrated in their individual work. Individual assistance was given as required.

Problem Statement

The purpose of this study was to evaluate the effectiveness of a specific, teacher-prepared, set of programed instructional materials for basic electrical theory when it was used as part of the instruction in a vocational high school course in electricity.

Specific Questions to be Tested

1. How well do the individual units of programed instructional material achieve the learning objectives for which they were intended?

2. How do students who use the programed instructional material as part of their total classroom instruction compare with students in conventional classes in achievement on a posttest in basic electrical theory?

3. How well do the students who use the programed instructional material retain the learning achievement?

4. How do students who use the programed instructional material as part of their total classroom instruction compare with students in conventional classes in achievement and retention of

(a) knowledge of basic electrical theory?

(b) comprehension of basic electrical theory?

(c) application of basic electrical theory?

where the terms knowledge, comprehension, and application were used as classifications of the cognitive domain as defined in the Taxonomy of Educational Objectives (Bloom, 1956).

5. How does the average time spent by individual students on the programed material compare with the time spent by students in conventional classroom presentation covering the same course content?

6. What is the students' attitude toward the

programed material?

Hypotheses

The above questions were restated in hypothesis form. Question 4 is tested by six hypotheses; each of these relates to only one of the three classifications, knowledge, comprehension, and application, in either the posttest or the retention test.

Hypothesis 1. 75% or more of the students in the experimental group will answer 75% or more of the items in each subtest correctly when each subtest is taken immediately after the preceding programed unit is completed.

Hypothesis 2. There is no significant* difference between the mean posttest scores of the experimental and the control group - with the effects of previous knowledge in mathematics factored out - when the programed instructional material is used as an integral part of the instruction for the experimental group.

Hypothesis 3. There is no significant difference between the mean retention test scores of the experimental and the control group - with the effects of previous knowledge in mathematics factored out - when the programed instructional material is used as an integral part of the instruction for the experimental group.

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*The level of significance is 0.05 for all hypotheses.

Hypothesis 4. There is no significant difference between the mean scores of the two groups for that part of the posttest that is classified as knowledge.[*]

Hypothesis 5. There is no significant difference between the mean scores of the two groups for that part of the posttest that is classified as comprehension.

Hypothesis 6. There is no significant difference between the mean scores of the two groups for that part of the posttest that is classified as application.

Hypothesis 7. There is no significant difference between the mean scores of the two groups for that part of the retention test that is classified as knowledge.

Hypothesis 8. There is no significant difference between the mean scores of the two groups for that part of the retention test that is classified as comprehension.

Hypothesis 9. There is no significant difference between the mean scores of the two groups for that part of the retention test that is classified as application.

Hypothesis 10. There is no significant difference between the means of the two groups for the time spent by students in learning the basic electrical theory either by programed instruction or by conventional classroom presentation.

Hypothesis 11. The attitude toward the programed

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[*] The means used in hypotheses 4 to 9 have the effect of previous knowledge in mathematics removed.

material of the students learning electrical theory by programed instruction is not significantly different from the attitude of a hypothetical population of unbiased subjects.

Need for the Study

There are several advantages that programed instruction can offer. The most important of these advantages is that programed instruction can make individual student progress possible. This is particularly desirable in a vocational-technical course in electricity, because ability and motivation of students entering such a course vary over a wide range. There may also be considerable difference in previous knowledge of electrical theory that individual students may have as a result of earlier industrial arts courses or from personal interests or hobbies. Programed instruction could therefore be used to make it possible for students to progress at their own rate. Different students will learn better with different teaching methods, and some students may learn more effectively with programed instruction. On the other hand there may be students in a group that learn less effectively with programed instruction. However, since programed instruction frees the teacher from some of the routine teaching tasks, he may be able to give such students some individual assistance. Nevertheless, the mean effectiveness for the total group must not be less than that of conventional instruction.

Even when the advantages of programed instruction are accepted, it is usually difficult to find a program that is suitable both in terms of learning objectives and in terms of the ability and motivation of the students. When a new program is developed in answer to a specific demand, its effectiveness must be determined in a situation that resembles its intended use as closely as possible before its use is continued by the person who has developed the program or by others. Such evaluation should be carried out in accordance with the recommendations that are available for such studies.

Limitations

1. The study was limited to students enrolled in the vocational electricity courses in a number of Alberta composite high schools. The experimental group was confined to one school. This limitation arose because the experimental group had to receive its instruction under controlled conditions that were best assured by confining this group to one school. The control group was randomly selected from the Electricity 12 classes of six different schools. No random assignment or random selection was possible for the experimental group due to the limited number of students enrolling in the Electricity 12 course. To compensate for this limitation in the experimental design, the statistical control of an analysis of covariance was used. The covariate used was the students' mark in

grade nine mathematics.

2. The pretest, posttest, and retention test instruments were paper-and-pencil type multiple choice tests. Results of such tests are to some extent influenced by the subjects' verbal ability.

3. The time spent by the control group in conventional classroom presentation was determined from information obtained from the six teachers teaching the control group subjects. It was difficult for these teachers to measure the exact time spent in teaching the content that corresponded to the content of the programed instructional material.

4. Student attitude was measured by a questionnaire. A questionnaire may not produce an accurate measurement of the students' attitude, particularly since it was not possible to obtain a real control group for the measurement.

5. The retention measure was influenced by the fact that both groups used some of the learning objectives that were under investigation in their continued study of electricity.

Assumptions

1. It was assumed that the teachers teaching the control group cover essentially the basic concepts of electrical theory that were outlined for the Electricity 12

course in the Curriculum Guide: Electricity 12, 22, 32 (Dept. of Ed., 1969), and that these concepts were not significantly different from the concepts used as learning objectives for the programed instructional material. Teachers who reported significant deviations from this content for their classes were not included in this study.

2. It was assumed that the teacher variable could be neglected. For the experimental group the teacher did not actively enter into the presentation of the material. The control group subjects were randomly selected from classes taught by six different teachers.

Definition of Terms

Effectiveness of a teaching method was evaluated by measuring the achievement after the instruction; by measuring the retention of the achievement; by measuring achievement in the cognitive classifications of knowledge, comprehension, and application; by measuring the time spent in reaching the learning objectives; and by measuring the students' attitudes toward the teaching method. (More discussion on the term effectiveness can be found in the Review of the Literature.)

Conventional Classroom Presentation for electrical theory is the teaching method where concepts are presented by the teacher in either an explanatory or exploratory manner involving the students in active participation and

using suitable audio-visual aids.

CHAPTER 2

REVIEW OF THE LITERATURE

The related literature was surveyed to determine what recommendations were made and what approaches were taken in evaluating the effectiveness of programed instruction. Particular attention was given to statements made about the necessity of validating programed instruction, about the term "effectiveness", and about different methods and designs for validation studies. A summary of other studies was included in this chapter.

Introduction

While a "teaching machine" was introduced by Pressey in the 1920's, it was not until the end of the 1950's that teaching machines and programed learning gained widespread attention among educators. This increased interest is reflected in a wealth of studies, observations, and comments about this teaching technique. This early literature was primarily concerned with more basic observations and theories, such as the difference between the "Pressey" type multiple choice program, the "Skinnerian" linear, constructed response program, and the "Crowder" branched program. Of course many studies concerned themselves with a comparison of effectiveness between programed learning and conventional classroom instruction. Unfortunately, these

studies were often interpreted in a very generalized manner, and this resulted in conflicting reports about the effectiveness of programed instruction. By the early sixties, the studies became more specific. It is evident that researchers realized that it is not "programed instruction" that is more or less effective, but that the individual program and the way it is used make the difference in effectiveness.

Need for Evaluation

Lumsdaine (1965) points out that evaluation of one program is not an evaluation of the method or vice versa. Each program must be evaluated on its own merits. Markle (1967) also says that programs are not guaranteed to work, just because they are called programs. In addition she points out that scientific investigation and experimentation is the only way to determine the factors necessary to make effective programs. The Joint Committee on Programed Instruction and Teaching Machines (1965) assumes that the program producer must be interested in the effectiveness of his program, but at the same time reporting the effectiveness of a program is of assistance primarily to the potential user. Green (1967) states that only the individual user can determine the effectiveness of a program in his situation in an unambiguous manner, but Green admits that such an evaluation is much too time consuming

to be carried out by the individual teacher who intends to use a program. The teacher must therefore rely on reported evaluations. Authorities generally agree that simple inspection of a program is not a reliable method of determining effectiveness (Glaser, 1963; Lumsdaine, 1965; Markle, 1967). In a study by Rothkopf (1963) twelve high school teachers and principals rated seven versions of a program to predict effectiveness. Their predictions correlated negatively (-0.75) with actual effectiveness. The summary of studies reviewed by this investigator (Table 1) indicates different effectiveness for different programs, and this again emphasizes the need for evaluation of each program.

While authorities generally agree that each program must be evaluated in an empirical study to determine its effectiveness, there seems to be a lack of evidence that this is done for all commercially available programs. Markel (1967) investigated 291 published programs and found that for 40% of these there was no evidence of testing available. This investigator tried to obtain further information on six programs on basic electricity that were listed in Hendershot (1969), and was able to obtain only three positive replies from publishers. None of the information given by these publishers regarding validity testing seemed to conform to the "Recommendations for Reporting the Effectiveness of Programed Instructional

Materials" (Joint Committee on Programed Instruction and Teaching Machines, 1965).

What is "Effectiveness"

Almost all studies that evaluate or compare the educational value of programed instruction or similar teaching methods use the term "effectiveness". However, this term is defined in many different ways, sometimes in a formal statement, sometimes by implication, and sometimes not at all. Lumsdaine (1965) says that

> "Effectiveness" refers to how well the program does, in fact attain certain prospective outcomes, how well it teaches whatever it was calculated to teach (rather than what it may teach), or, in other words, the extent to which content is learned, or the extent to which stated objectives are attained by students who use the program in a particular way (p. 274).

The Joint Committee on Programed Learning and Teaching Machines in its "Recommendations for Reporting the Effectiveness of Programed Instructional Materials (1965)" suggests that a formal study should provide behavioral indices of what the student can do after going through a program, but that it should also include measures of retention, transfer of skills, attitude, and time spent in instruction. A measured gain of achievement is part of all explicit or implicit definitions of effectiveness, however, some authors point out that such measures of gain must be accompanied by a statement of objectives for the program, and that the measurement must show how far these

objectives have been reached (Deterline, 1967; Green, 1967; Knezevich, 1970). Other researchers have put the main emphasis on retention of such achievements (Ellis, 1964; Opdycke, 1964), or on understanding, transfer, and application (Balson, 1969; Deterline, 1967; Silverman, 1967; Wing, 1967). Student attitude is another important factor. A study by Ellis (1964) indicates that student attitude correlates with the amount of learning that takes place. While a correlation does not determine a cause and effect relationship, several authors agree that a positive attitude of students toward a teaching method will promote present and future learning (Hughes, 1963; Lumsdaine, 1965; Opdycke, 1964).

Time spent to reach a certain achievement level is another important factor in the definition of effectiveness - even though Lumsdaine (1965) suggests the term efficiency for such measures. Deterline (1969/70) reports a very direct use of the time factor in "Performance Contracting: The Texarcana Project". In this project a commercial company was paid in accordance with the time it took to increase each student's reading ability by one grade level. For 80 hours of student time the payment was $80.-. If the study time was reduced to 60 hours, the payment increased to $110.-, while for 105 hours it dropped to $60.-. If a student took longer than 105 hours -- the time it took under previous instructional

methods -- no payment was received. The contracting company used primarily programed material to obtain this goal. This project provides an example of the importance that some educators attach to the time factor. Deterline predicts that the future will bring more demand for this type of "accountability" or "educational performance".

Cost is another factor that should be considered, but none of the authorities make the demand that cost must be directly reported, assuming that cost can be calculated when time and cost of materials and possible machinery is known. Knezevich (1970) and Kopfstein (1968) compare costs of computer administered instruction (CAI) with the cost of programed instruction and the cost of conventional instruction. Both conclude that at the present time CAI is too costly for general use, but they also observe that the cost of CAI is decreasing, while the cost of conventional instruction is increasing.

Lumsdaine (1965) and Zachert (1964) add one more factor that may not belong directly with the term effectiveness, but that should, nevertheless, be considered when evaluating a program. They use words such as practicality, feasibility, or suitability. Both authors also emphasize that the evaluation of a teaching method must consider all the various factors together.

When time is used together with achievement in the determination of effectiveness, another problem arises.

When one method produces 50% better achievement, but also uses 50% more time than another method, we may not be able to tell which method is more effective. Lumsdaine writes about this dilemma:

> Of course it is possible to simply report two separate sets of facts. This is about the best possible solution at present; it is not a very good long range solution, because it leads to no decisive basis for preferring one program over another when one program scores better in terms of achievement, but the alternate program scores better in terms of time. Gain in achievement level has sometimes been expressed as an "efficiency" ratio of gain divided by time. Objections to this procedure stem from such considerations as nonlinearity of achievement-gain scales. These considerations, however, do not controvert the need to take time into account in some fashion (p. 309).

After further discussion Lumsdaine concludes that "for the present time no single achievement-time index seems to be defensible as a single figure of merit for a program's instructional efficiency (p. 310)."

Jacobs (1966) and Kopfstein (1968) suggest that effectiveness should be expressed as a ratio of achievement over time. Hughes (1963) and Silverman (1967) seem to agree with Lumsdaine in their recommendation to report both achievement and time as separate items. The recommendations of the Joint Committee on Programed Learning and Teaching Machines (1965) leave it up to the individual investigator to use the one method or the other.

Of the thirty-five studies summarized in Table 1, none use an achievement-time ratio to report effectiveness; three hold time constant and report differences in achievement;

one reports time needed to reach a predetermined achievement; eleven report achievement and time as separate measurements -- however, only in one of these eleven studies does lower achievement coincide with less time, thus leaving it up to the reader to determine the relative importance of each factor. Twenty studies report no direct comparison of time. In most of these studies it can be assumed that the experimental design did not make provisions for measuring variations of time, or that time was not considered to be significantly different.

Summarizing the various factors that should be included in a report of the efficiency of a teaching method and in particular of programed instructions, it is evident that different authorities and investigators will place different emphasis on different factors, but a report that would include the following measures would likely satisfy most of the demands made in the literature: (1) achievement of stated objectives, (2) retention of achievement gains, (3) transfer and understanding, (4) time required for instruction, (5) attitude of the students toward the instructional method. Given an evaluation of the above factors would also assist a potential user of the program in determining the practicality or suitability and the expected cost of using the program.

Absolute Standards vs. Comparison

While there is little dispute in the literature about the major factors that constitute effectiveness, there seems to be some controversy about how to evaluate it. Most authors accept the comparative study as the best method of evaluation, but some authorities seem to be in favor of an absolute standard of expected achievement. Gagne, in a discussion about this matter (reported by Hughes, 1963), says that from the results of a comparative study "we cannot really say a program is better than a lecture, because, of course, that depends on how good the lectures were (p. 42)." Morse, in the same discussion points out that "classroom instructional method", "standard lecture", "conventional class", "lecture method", and "normal way of instructing" are often not very standard. Green (1967) would prefer a set of specifications of what the program does over a statistical statement of comparison with an "unknown" standard. Bloom (1968) is more concerned with the amount of "mastery" that the individual student reaches, and he favors setting standards of mastery apart from comparisons with other students. Deterline (1967) accepts such standards as the 90/90 level that were used in another study (Robertson, 1963). (In a 90/90 standard, 90% of the students must complete 90% of the items on a test correctly.) While the Texarcana Project reported by Deterline (1969-70) is not a research study,

but a practical project, the evaluation of effectiveness is done by a standardized test without the use of a comparative control group. It could, however, be argued that even absolute standards are usually influenced by experience with achievements of students at earlier times, and that they are at least to some extent comparative.

There are several critics of the absolute standards for evaluation. Deese, in the before mentioned discussion (reported by Hughes, 1963), challenges Gagne's demand for absolute standards. Deese points out that, when we look for retention and transfer, we can hardly expect a perfect score. Glaser, in that same discussion, adds that we can easily set the standards so low that even a poorly prepared program reaches them, and we would not be forced to improve the training program. He suggests that, at least at the present time, we need the results of comparative studies. Opdycke (1964) observes that comparative studies are still viewed as the more convincing evidence. Jacobs (1966) also considers a control group as necessary. Flanagan (as reported by Lumsdaine, 1965) describes the use of absolute standards at the present time and with present measures of attainment as indefensible and even dangerous. Taber (1965) raises the question whether a test should have a mastery ceiling. Such a test can show that a program teaches to this level of mastery, but one could not find out how much more the student learned and how far

he can transfer this knowledge to a more complex situation. Of the thirty-five studies summarized in Table 1, thirty-three use comparison as evaluation, while only one reports the level of achievement on a given test by the experimental group without comparison.

Experimental Design

Effectiveness, whether measured by an absolute standard or by comparison, must be evaluated in an experimental study. In order for the conclusions to be valid, the experimental design must limit the number of uncontrolled variables to a minimum. Taber, et al. (1965) gives some examples of evaluative designs with or without control groups. These examples reach from simple pretest-posttest procedures to the more complex sequence of pretest programed instruction, interim test, other instruction posttest. Deterline (1970) points out that, because programed instruction is a highly structured and easily controlled method of instruction, it has led to more widespread evaluation of teaching methods by student evaluation. Green (1967), on the other hand, says that the application of experimental control and the logic of test theory as applied to programed instruction is very difficult and inadequacies and confusion in this lead to inconclusive results. Gilbert (1960) is vigorously opposed to highly controlled and artificial experimental investigations, because they are only used to prove some preconceptions,

and the unlimited variety of human factors make it virtually impossible to provide the desired control in an experiment. Guba (1969) states that it is of limited practical value to use an evaluation paradigm that emphasizes control when invited interference is needed.

At first glance it may seem simple to control the administration of programed instruction adequately, particularly when programed instruction is the only method used for both groups or, at least, for the experimental group. Of the thirty-five studies summarized in Table 1, twenty-eight use programed instruction exclusively for the experimental group, however, the seven studies that use programed instruction intergrated with other forms of instruction seem to indicate that such integration is more effective both in terms of achievement and in producing better student attitude. Hartley (1971) says that "Of twelve studies known to the author which have compared programed instruction alone with programed instruction 'integrated' with the teacher, eleven have found this latter situation to produce better results (p. 215)." Other investigators who have used programed instruction in experimental and practical applications also warn that exclusive use of programed instruction will reduce its effectiveness significantly both in terms of actual achievement as well as in student motivation or attitude (Can. Teachers' Federation, 1965; Crist, 1969; Goldbeck, 1962;

Hughes, 1962; Stavert, 1967). It seems that the exclusive use of programed instruction to allow for maximum control is in itself a very strong undesirable influence. Deterline (1967) as well as Lindvall and Bolvin (1967) believe that the greatest advantage of programed instruction is the possibility for individualization of instruction, and these authors point out that this individualization of instruction makes experimental control very difficult.

The Joint Committee on Programed Instruction and Teaching Machines (1965) recommends that the design used in evaluation should be similar to the situation of intended use of the program. At the same time it is recommended that evaluation should be carried out under controlled conditions. These two recommendations may sometimes be difficult to reconcile. This dilemma is somewhat alleviated by the recommendation that the program producer should specify the intended conditions of usage in the program manual. Lindval and Bolvin (1967) believe that one of the problems in the use of programed instruction is improper application, which would, of course, reduce effectiveness. However, in practical applications it may not always be possible to use a program under the same "ideal" conditions that a controlled study can provide. The Canadian Teachers' Federation (1965) reports seventeen studies conducted by teachers using

commercially prepared programs in practical situations. The results seem to be unfavorable to the programs. Nine studies showed no significant difference, four showed the control group significantly higher, two showed the experimental group significantly higher, and two studies were inconclusive.

One more study that deserves attention with regard to the experimental design is that reported by Hartley, Holt, and Swain (1970). The study was set up to determine the effect of pretest and interim tests on the posttest results. The outcome showed that the interim tests contributed significantly to the effectiveness of the instruction. The pretest did not have any significant effect when interim tests were used, but did have a significant effect when no interim tests were used. It should be observed that the total average time for the instruction was thirty-one minutes with the interim tests, and twenty-two minutes without.

Recommendations by the Joint Committee on Programed Instruction

One of the most useful pieces of literature in designing a study on the effectivenss of programed instructional material is the *Recommendations for Reporting the Effectiveness of Programed Instructional Material* which were prepared by the Joint Committee on Programed Instruction and Teaching Machines (1966), and in particular the

Supplement II to these recommendations: Recommendations for the Preparation of Technical Reports (1966). These recommendations summarize many of the points that were made by previous authors, and they are, in turn, considered as an accepted standard by authors that address themselves to the same topic in the following years. However, these recommendations are not a cookbook prescribing a rigid structure, rather they leave enough flexibility to make them useful in a wide variety of different situations.

The recommendations include many items that can be considered standard for technical reports. In addition they discuss many items that are more specifically related to testing the effectiveness of programed instructional materials, such as measurement of the material's specific effect on achievement, retention, application of knowledge and skills, time, and motivation.

The need for pre- and post-tests is emphasized and it is pointed out that, when other than standard tests are used, their content and objectives must be described. Care should be taken to assure that samples of items in the test are independent of samples in the program, and that the program does not merely coach the student on a particular sample of items. The recommendations make no specific demand for a control group, but a section on comparative studies is included.

Other Studies

The studies reviewed and summarized in Table 1 are those dealing with the effectiveness of programed instruction. However, in some studies the evaluation of effectiveness is only a secondary objective. The studies vary widely in their experimental design. Some are relatively rigidly controlled, others are conducted under more practical conditions; some of these latter ones lack the strict control usually required for research reports.

The following abbreviations are used in Table 1; these abbreviations refer to the experimental group (the group using programed instruction) unless otherwise indicated under "additional information".

SH	significantly higher	.05 level or better
SL	significantly lower	
NSD	no significant difference	
NR	not reported	
higher	No statistical evaluation of the difference was reported, but the data indicate a large difference that would likely be significant.	
lower		
integrated	Programed instruction used together with other types of instruction.	

Some of the studies listed in Table 1 investigated additional concepts of programed instruction, such as the effectiveness in providing for individual instruction and in freeing the teacher from routine tasks. On the other

TABLE 1

SUMMARY OF OTHER STUDIES

Study reported by	Control group	Achievement	Retention	Transfer	Time	Motivation	Additional information
Balson, M.	yes	SH	NR	NSD	NR	NR	
Blyth, J. W.	yes	20% higher)					French
	yes	20 points higher)			same	NR	German
	yes	10 points higher)					Logic
Brown, O. R.	yes	SH	SH	NR	NR	NR	
Bushnell, D. S.	yes	SH	NR	NR	less	lower	PI alone
	yes	SL	NR	NR	less	higher	Integrated
	yes	SL	NR	NR	more	lower	Conventional
Carpenter, C. R.	yes	NSD	NR	NR	NR	lower	
Cooke, L. C.	yes	SL	NR	NR	NR	NR	
Crist, R.	no	effective to create homogeneous groups					
Dickson, G. J.	yes	SH	NR	NR	NR	NR	PI used as review
Feir, D. L.	yes	lower	NR	NR	less	NR	
Feldhusen, J. F.	yes	NSD	NSD	NR	NR	higher	
Francis, F.	yes	lower	NR	NR	NR	same	
Goldbeck, R. A.	yes	SH	NR	NR	NR	NSD	Integrated
Greatsinger, C.	yes	NSD	NR	NR	SL	NR	
Hatch, R. S.	yes	SH	NR	NR	NR	NR	Integrated
	yes	NSD	NR	NR	NR	NR	PI alone
	yes	NSD	NR	NR	NR	NR	Conventional
Holt, H. O.	yes	SH	SH	SH	NSD	higher	
Hough, J. B.	yes	NSD	NR	NR	NR	NR	
Hughes, J. L.	yes	NSD	NR	NR	SL	NR	

TABLE 1 (continued)

Study reported by	Control group	Achievement	Retention	Transfer	Time	Motivation	Additional information
Ives, J. M.	yes	NSD	NR	NR	NSD	NR	
Jamison, G. H.	yes	NSD	NR	NSD	NR	NR	
Jardine, D. K.	yes	NSD	NR	NR	NR	NR	
Kopfstein, F. F.	yes	NSD	NR	NR	same	NR	Integrated
Larue, M. A.	yes	NSD	NR	NR	20% less	NR	
Managemt. Info.	yes	SH	NR	NR	NR	NR	On 5 out of 12 subtests
O'Donnell, L. H.	yes	SH	NR	NR	less	NR	
Price, E.	yes	NSD	NR	NR	NR	NR	
Reed, H. E.	yes	NSD	NR	NR	NR	NSD	
Richards, D. M.	yes	NSD	NR	NR	NR	NR	
Robertson, P. L.	no	90/90 criterion reached					
Robinson, L. W.	yes	SH	NR	NR	NR	lower	
Roebuck, M.	yes	SH	NR	NR	NR	NR	Integrated
Silverman, R. E.	yes	NR	NR	NR	same	lower	PI allowed extended curriculum
Stavert, G. S.	yes	10% low	NR	NR	less	lower	PI alone
	yes	4% high	NR	NR	less	higher	Integrated
Smith, H. N.	yes	NSD	NR	NR	less	NR	
Smith, W. I.	yes	SH	NR	NR	NR	higher	Integrated
Wing, R. C.	yes	SH	NR	NR	NR	less	Group 1
	yes	NSD	NR	NR	NR	less	Group 2

hand, some problems are investigated that may interfere with the effectiveness of programed instruction. Some of these problems are, the difficulties in providing flexibility so that students can indeed proceed at their own rate of speed without being forced directly or indirectly to conform to some average or to some expectation. Boredom is another problem mentioned particularly when a long program is used as the only form of instruction.

One general observation that could be made is that many of the studies that were reviewed reported only one or two measurements. Usually posttest achievement and time were reported. Only a few studies reported the additional measures of transfer, retention, or motivation.

One very thoroughly conducted evaluation of a program in basic electricity was reported independently by Bell Telephone Co. (1961), Holt (no date given), again by Holt (in Hughes, 1963), and by Woolman (1962). The program was prepared specifically for the Bell Telephone Company. Separate results were reported for learning of facts, learning of concepts, retention of facts, and retention of concepts. Mean and range were reported for the time used by the subjects in the experimental group, and this was compared with the time used by the control group. The results showed that learning of facts and learning of concepts were significantly higher for the experimental group. This difference was retained as indicated by the

retention test results. There was no significant difference between the two groups in the time they spent in instruction.

Summary and Discussion

The review of the literature on measuring the effectiveness of programed instruction shows general agreement on some issues, but it leaves other problems unresolved. Most authors agree, that each program must be evaluated on its own merits, and that only empirical data derived from student performance should be considered as a basis for making judgements. It becomes evident that effectiveness is a multivariate concept and that no single index can satisfy the various demands made for effectiveness measures by different authorities and researchers. Some authors seem to emphasize retention and transfer over immediate achievement results; in some applcations time is more important than in others, and the importance of motivation and attitude is stressed to varying degrees. While the debate about comparative evaluation or absolute standards seems unresolved, almost all studies use the comparative design. The need for maximum experimental control should be beyond question, however, there are several authors who believe that the results of rigidly controlled experiments bear little resemblance to actual applications and are therefore of little value to the practitioner. One term that is often used in the literature is "conventional

instruction". However, this term is not satisfactorily defined in a generally applicable way in the reviewed literature. This may be due to the fact that conventional instruction may vary over a wide range among different situations.

When the listing of the thirty-five studies in Table 1 is further summarized, it can be seen that in sixteen studies there was no signficiant difference in the immediate (posttest) achievement; in thirteen studies the experimental (programed instruction) group was significantly higher, and in only two studies was this group significantly lower in the immediate achievement when compared with a control group using conventional instruction. In the remaining studies there was no statistical comparison for this measure. Ten studies reported lower time measures, and none reported significantly higher times used. For all other studies the time was either kept the same, or in many cases not reported.

CHAPTER 3

EXPERIMENTAL DESIGN

This chapter outlines the experimental design that was used in this study to evaluate the effectiveness of the programed instructional material. The design attempted to incorporate most of the recommendations made in the literature and in particular those made by the Joint Committee on Programed Learning and Teaching Machines (1966). This chapter describes the population used in the study, the subjects in the experimental and in the control group, the outline of the instructional and evaluative procedures, and the test instruments.

Student Population

The subjects used in this study were students enrolled in the Electricity 12 course in six Alberta composite high schools. The Electricity 12 course is the first of the Electricity 12-22-32 series of vocational high school courses which lead to an apprenticeship or to a technology program in electricity. The Electricity 12 course is a vocational option in which students enrol voluntarily. At the time of this study the Electricity 12 course was offered in fifteen composite high schools in Alberta, however, only six schools and seven instructors were included in this study. This limitation was necessary to achieve a

certain amount of uniformity in terms of the material covered and the time span available for instruction. (See description of the control group.)

The total number of subjects included in the study was ninety-nine. The chronological age ranged from fifteen to eighteen. All subjects were male.

The experimental group consisted of twenty-five students enrolled in the Electricity 12 course in Victoria Composite High School, Edmonton. The experimental group received its instruction in basic electrical theory through the programed material that is evaluated in this study. The supplementary instruction was completed by the students in the experimental group under the instruction of this investigator.

The control group consisted of twenty-five students who were randomly selected from a total of seventy-four students which were enrolled in the Electricity 12 course in six different composite high schools in Alberta. The population for the random sample was limited to those Electricity 12 students who covered essentially the same electrical theory content as the experimental group. This was determined by the indication of the participating teachers that they followed the *Curriculum Guide: Electricity 12, 22, 32* (Dept. of Ed., 1969). The population for the random sample was further limited to those classes that covered the material over the time span of approximately

five months (the same time span that the experimental group used), and to those classes whose teachers were in a position to participate in the study.

In order to reduce any possible bias that might arise because the experimental group was limited to one school and to one instructor, and could not be randomly selected from a larger population, the analysis of covariance was used to test hypotheses 2 to 9. The students' grade nine mathematics mark was used as a covariate. A pilot study had been used to confirm that the mathematics mark was the only grade nine mark that correlated significantly with the performance on the posttest.

A pretest was included in the experimental design to determine whether there was any significant difference between the two groups in the knowledge of electrical theory that they had before the instruction started. The pretest was also used to determine whether there was a significant correlation between the initial knowledge the subjects had in electrical theory and their achievement in the posttest and the retention test.

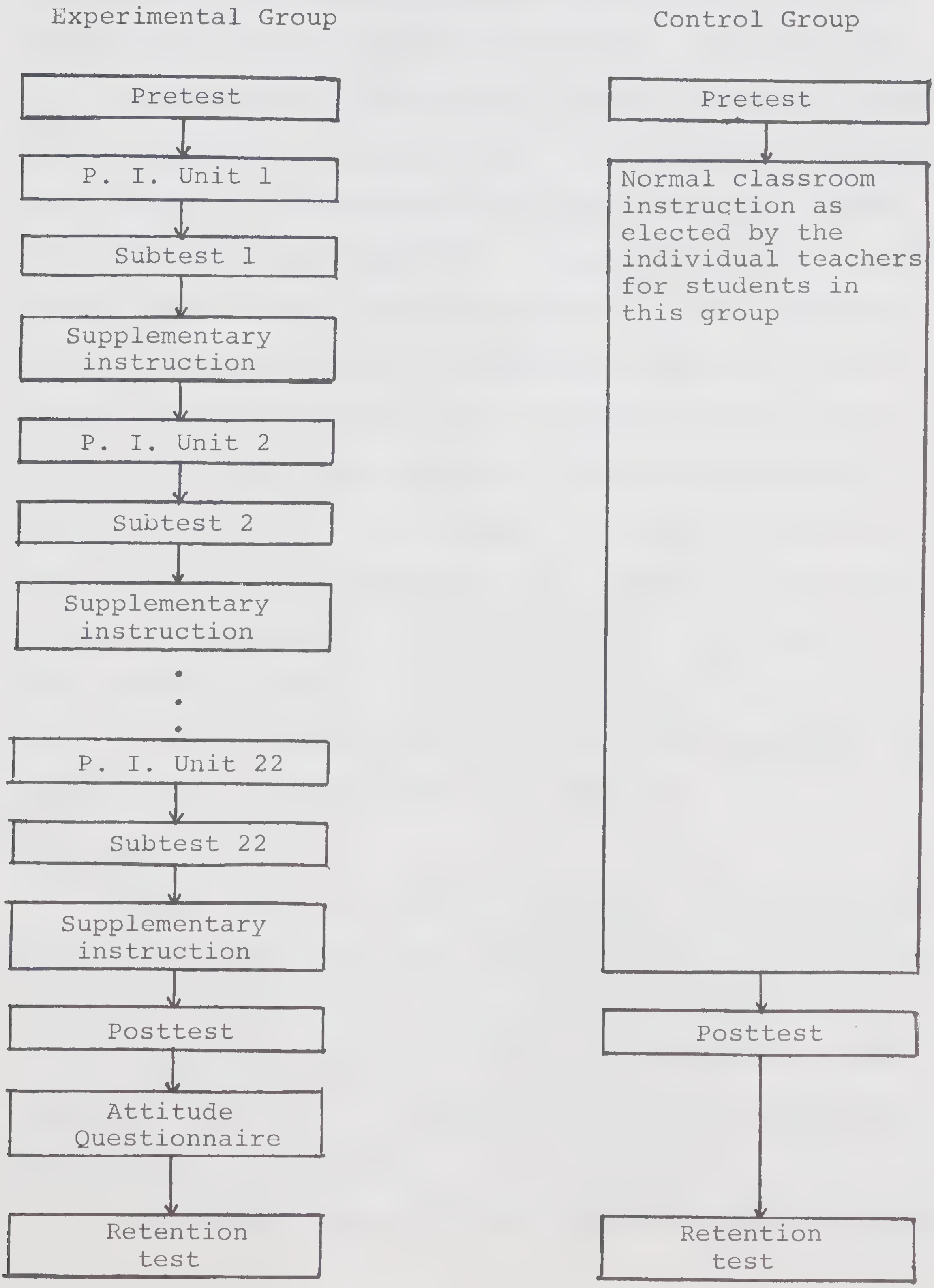
Instructional and Evaluative Procedures

Figure 1 shows a schematic outline of the instructional and evaluative procedures for both the experimental group and the control group.

The pretest was administered to both groups before

FIGURE 1

SCHEMATIC OUTLINE OF EXPERIMENT PROCEDURES



any instruction was started.

Each student in the experimental group was given a detailed course outline check list that showed each item of work that the student had to complete. Each new topic in the course outline was usually introduced by a programed instructional unit. The programed units were available to the students in mimeographed form and became part of the student's notes when completed. Immediately after the programed instructional unit was completed by the individual student, he was given the corresponding subtest. The subtest was usually corrected as soon as the student handed it in. Any errors were discussed with each individual student at that time. The student then went on to complete the related experimental work, textbook references, and problem assignments as listed in his course outline. When demonstrations were necessary, they were given when all, or a smaller group, of the students had completed the related work. (See Appendix A for samples of the p. i. materials.)

Each student recorded his own starting and finishing time for each programed unit and reported it to the teacher. This time included the completion of the subtest.

The posttest was given after all students had completed the outline. The attitude questionnaire was given the day after the posttest.

The control group subjects received their instruction

in basic electrical theory as their teachers would normally teach it in their Electricity 12 course. This instruction generally included lecture-discussion presentations, experimental work, problem assignments, textbook references, and demonstrations. The control group teachers were asked to keep a record of the time spent with the class in lecture-discussion presentations of the basic electrical theory as outlined in the posttest matrix. The posttest was administered by each teacher after the instruction on basic electrical theory was completed.

The retention test was given to both groups approximately five months after the posttest had been administered.

The Test Instruments

The main criterion test (pre-post) and the retention test were multiple choice type. They were each constructed from a test matrix that determined the electrical concept as well as the learning objective for each item. Only the first three classifications of Bloom's *Taxonomy of Educational Objectives* (1959) were used as learning objectives. Many of the test items were contributed by other teachers of Electricity 12 classes, and all items were subjected to the judgement of thirteen teachers who participated in a pilot study to validate these tests.

The test validation pilot study involved 151 Electricity 12 students and thirteen teachers on a province-wide

basis. The test validation was done using an existing program, TEST04, of the University of Alberta's 360/67 Computer System. This evaluation provided a reliability measure for each test, as well as an item analysis including indices for item reliability, discrimination, and difficulty. The reliability index for each test was based on the Kuder-Richardson 20 formula. Items with a low reliability index were revised or replaced using other information given by the item analysis. The results of the TEST04 program are shown in Table 2 for both the posttest and the retention test.

TABLE 2

RESULTS OF TEST ANALYSES

Measure	Posttest	Retention t.
Number of students	151	75
Number of items	95	60
Test mean: raw score	51.50	37.88
Test mean: precent	54.21%	63.63%
Standard deviation: raw score	13.26	9.35
Standard deviation: percent	13.97%	15.60%
Variance: raw score	176.79	80.75
Reliability: KR-20	0.8914	0.8641
Mean: "knowledge" items	55.5%	68.0%
Mean: "comprehension" items	52.4%	55.2%
Mean: "application" items	54.9%	64.1%

The retention test used items that were different from items in the posttest, however, the pretest consisted of a random sample of forty items taken from the ninety-five items in the posttest. It was felt that a longer pretest of items that are largely unfamiliar to the students would only frustrate the students and would not produce true results.

Each of the subtests was constructed based on the specific electrical concepts that were the teaching objectives for each unit of programed instruction. Individual subtests had from nine to fourteen items with a total of 245 items for all twenty-two subtests. Of these 245 items 185 came from an existing test library and most of these had a difficult level indication from previous applications. The average of the available difficulty levels was 0.64.

The Questionnaire

The objectives of the attitude questionnaire were determined with some assistance from a questionnaire and its results reported by Woolman (1962). The questionnaire was applied in a pilot study and some revisions were made. The questionnaire has one favorable and one unfavorable question for each attitude or motivational concept to be evaluated. The questions were arranged on a random basis. In evaluating the questionnaire the rating for the

unfavorable items was taken from one to five on a Likert scale, while the favorable items were counted from five to one. This method was intended to reduce any possible bias that could result if students tend to agree more than to disagree with any given question. (See Appendix B for the subtests, the test construction matrices, the pretest, the posttest, the retention test, and the questionnaire.)

CHAPTER 4

STATISTICAL ANALYSIS

The purpose of the statistical analysis was to investigate the data derived from the experiment in order to determine the effectiveness of the programed instructional material that was used by the experimental group. The data collected during the study were first subjected to a preliminary analysis to determine whether there was any significant correlation between the subjects' previous knowledge in mathematics and electricity and their achievement in the posttest and the retention test. The data were then further analysed to determine the validity of the eleven hypotheses stated in Chapter 1.

Preliminary Analysis

The purpose of the preliminary analysis was to determine whether the subjects' grade nine mathematics mark and their previous knowledge in electrical theory (as measured by the pretest) correlated significantly with their performance in the posttest and in the retention test. The results of this preliminary analysis were used to determine which of these two factors would be included as a covariate in the analysis of covariance procedures that were used to test hypotheses 2 to 9.

Table 3 shows the correlation for the grade nine

mathematics mark and the pretest results with the post-test and the retention test results. The pretest results did not correlate significantly with either the posttest or the retention test results, and were, therefore, not included as a covariate in the analyses of covariance. The grade nine mathematics marks however, correlated significantly with both tests and were used as the covariate in the analyses of covariance for hypotheses 2 to 9.

TABLE 3

CORRELATIONS FOR SUBJECTS' PREVIOUS KNOWLEDGE IN MATHEMATICS AND ELECTRICITY WITH POST- AND RETENTION TEST

	Post-test	Sign.	Retention test	Sign.
Grade nine math mark	.5118	.01	.3851	.05
Pretest results	.3463	no	.2431	no

The preliminary analysis also indicated that the two groups were not significantly different in terms of previous knowledge in mathematics and in electrical theory. The means for these two measures are shown in Table 4.

TABLE 4

COMPARISON OF GROUP MEANS IN GRADE NINE MATHEMATICS AND PRETEST

	Exp. Gr.	Contr. Gr.	Sign.
Grade nine math.	55.84	56.72	no
Pretest	13.92	13.32	no

Hypothesis 1 Test

Hypothesis 1 stated that 75% or more of the students in the experimental group will answer 75% or more of the items in each subtest correctly when each subtest is taken immediately after the preceding program unit is completed.

The individual student marks for each subtest are shown in Table 5. Table 5 also shows the percentage of correct items for the total of all subtest items for each student, as well as the average for each subtest, and the percentage of students completing 75% or better for each subtest.

In sixteen of the twenty-two subtests more than 75% of the students scored 75% or better of the subtest items correctly. In the other six subtests this standard was not reached. For the total of all subtest items 92% of the students reached a score of 75% or better. The mean for all subtests was 82.5%, with a range from 75% to 96%.

TABLE 5

SUBTEST RESULTS

Test No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Average all items
No. of items in each test	12	10	11	9	10	10	10	13	10	10	11	13	11	10	11	10	14	10	13	14	13	10	
Student																							
A	6	5	7	8	5	7	7	12	5	6	9	6	9	8	8	6	10	10	10	13	11	8	72%
B	12	10	10	8	9	10	9	10	9	10	10	12	11	6	8	10	14	10	13	14	13	10	93%
C	10	8	9	7	8	8	8	11	9	8	11	10	10	8	9	8	13	10	12	7	11	8	83%
D	12	10	11	8	9	10	9	11	10	10	10	10	7	7	8	8	8	7	12	8	10	9	83%
E	10	10	11	9	9	10	9	10	9	10	10	12	10	8	7	10	12	8	13	14	13	9	92%
F	8	10	7	9	7	10	7	8	6	7	7	13	9	8	10	7	13	9	12	13	13	8	82%
G	6	8	7	7	9	10	9	9	9	10	8	10	10	9	6	9	9	8	12	9	11	8	79%
H	10	10	8	9	8	10	9	11	9	10	8	10	10	8	7	9	8	9	9	10	12	7	82%
I	9	9	10	9	9	10	10	12	10	10	10	13	9	8	8	9	8	6	12	14	9	10	87%
J	10	8	10	9	9	10	9	13	10	10	10	12	11	8	7	8	10	8	10	10	13	10	88%
K	11	9	11	8	7	9	7	9	7	8	11	10	8	6	10	8	12	9	11	7	11	8	80%
L	7	9	9	7	8	9	8	11	8	7	10	12	9	8	7	8	10	8	11	11	12	8	80%
M	6	9	7	9	3	10	7	11	7	6	9	9	7	8	8	5	12	8	10	12	11	9	75%
N	9	10	11	8	7	10	8	10	7	8	10	10	7	5	7	6	10	6	10	13	7	7	76%
O	7	8	8	8	8	10	10	10	8	10	7	11	8	5	9	9	10	9	13	8	12	10	81%
P	10	8	11	10	9	9	9	10	10	9	11	10	9	9	10	8	11	7	8	9	10	7	83%
Q	9	8	7	8	8	9	5	10	5	7	7	6	6	6	9	8	10	9	10	9	8	10	71%
R	4	10	9	7	9	10	7	11	10	9	8	11	10	9	10	8	12	10	11	12	12	7	84%
S	10	7	7	7	8	9	7	9	7	7	8	9	11	10	11	9	8	10	13	7	9	7	78%
T	12	10	11	8	9	10	10	13	10	10	8	11	10	9	8	7	12	10	10	9	12	9	89%
U	8	9	8	9	6	9	9	8	8	7	6	11	9	8	9	10	12	10	12	12	12	9	82%
V	10	10	9	7	10	10	9	12	9	9	11	11	9	8	8	8	12	9	11	12	11	8	87%
W	11	10	9	8	8	10	9	11	6	10	7	10	7	9	8	8	10	7	11	11	9	7	80%
X	10	8	10	7	9	10	8	11	9	10	11	11	9	9	11	8	14	10	13	14	13	10	92%
Y	8	9	9	9	9	10	10	12	10	10	9	11	10	9	11	9	13	10	13	12	12	9	92%
% average each test	75	89	82	89	81	96	84	82	83	87	82	81	82	78	78	81	78	87	87	77	85	85	82.5%
% students over 75%	64	92	76	72	88	96	72	84	68	72	84	84	80	76	76	80	80	84	92	64	80	76	92%

Since hypothesis 1 refers the 75/75 standard to each individual subtest, this hypothesis must be rejected.

Hypothesis 2 Test

Hypothesis 2 stated that there is no significant difference between the mean posttest scores of the experimental and the control group -- with the effects of previous knowledge in mathematics factored out -- when the programed instructional material is used as an integral part of the instruction for the experimental group.

This hypothesis was tested using a one-way analysis of covariance with the posttest results as the main criterion. The grade nine mathematics mark was used as the covariate. An existing analysis of covariance program, ANCV10, of the University of Alberta's 360/67 Computer System was selected for this evaluation.

The adjusted results (with the effects of the covariate removed) of the analysis of covariance for the posttest scores are shown in Table 6.

TABLE 6

ADJUSTED ANALYSIS OF VARIANCE: POSTTEST

Source	D.F.	Mean Sq.	Adj. _F_	Level of Sign.
Grp.	1	763.45	39.52	<0.001
Wth.	147	19.31		

The _F_-ratio of this analysis of covariance indicated that the difference between the two group means for the posttest results was significant at a level smaller than 0.001. The adjusted means for the posttest are shown in Table 7. These observations show that the posttest mean for the experimental group was significantly higher than that of the control group.

TABLE 7

ADJUSTED MEANS: POSTTEST

	Raw Score	Percent
Experimental group	62.34	65.43%
Control group	48.78	51.35%

Hypothesis 2, that there is no significant difference between the two groups in the posttest results, must be rejected.

Hypothesis 3 Test

Hypothesis 3 stated that there is no significant difference between the mean retention test scores of the experimental group and the control group -- with the effects of previous knowledge in mathematics factored out -- when the programed instructional material is used as an integral part of the instruction for the experimental group.

This hypothesis was tested in the same way as hypothesis 2, except that the retention test scores were used as the main criterion.

The adjusted results of the analysis of covariance for the retention test are shown in Table 8.

TABLE 8

ADJUSTED ANALYSIS OF VARIANCE: RETENTION TEST

Source	D.F.	Mean Sq.	Adj. F	Level of Sign.
Grp.	1	520.95	37.95	<0.001
Wth.	147	13.85		

The F-ratio of this analysis of covariance indicated that the difference between the two group means for the retention test results was significant at a level smaller than 0.001. The adjusted means for the retention test are shown in Table 9. These observations show that the retention test mean for the experimental group was significantly higher than that of the control group.

Hypothesis 3, that there is no significant difference between the two groups in the retention test results, must be rejected.

TABLE 9

ADJUSTED MEANS: RETENTION TEST

	Raw score	Percent
Experimental group	40.11	66.85%
Control group	28.94	48.23%

Hypothesis 4 Test

Hypothesis 4 stated that there is no significant difference between the mean scores of the two groups for that part of the posttest that is classified as knowledge.

This hypothesis was tested in the same way as hypotheses 2 and 3, except that the scores used were those of the part of the posttest that was classified as knowledge.

The adjusted results of the analysis of covariance for the knowledge part of the posttest are shown in Table 10.

TABLE 10

ADJUSTED ANALYSIS OF VARIANCE: POSTTEST, KNOWLEDGE PART

Source	D.F.	Mean Sq.	Adj. F	Level of Sign.
Grp.	1	400.91	22.01	<0.001
Wth.	47	19.21		

The F-ratio of this analysis of covariance indicated that the difference between the two group means for the knowledge part of the posttest results was significant at a level smaller than 0.001. The adjusted means for the knowledge part of the posttest are shown in Table 11. These observations show that the experimental group mean for the knowledge part of the posttest was significantly higher than that of the control group.

TABLE 11

ADJUSTED MEANS: POSTTEST, KNOWLEDGE PART

	Raw Score	Percent
Experimental group	21.69	72.30%
Control group	16.03	53.43%

Hypothesis 4, that there is no significant difference between the two groups in the results of the knowledge part of the posttest, must be rejected.

Hypothesis 5 Test

Hypothesis 5 stated that there is no significant difference between the mean scores of the two groups for that part of the posttest that was classified as comprehension.

This hypothesis was tested in the same way as the

three preceding hypotheses, except that the scores used were those of the part of the posttest that was classified as comprehension.

The adjusted results of the analysis of covariance for the comprehension part of the posttest are shown in Table 12.

TABLE 12

ADJUSTED ANALYSIS OF VARIANCE: POSTTEST, COMPREHENSION PART

Source	D.F.	Means Sq.	Adj. F	Level of Sign.
Grp.	1	210.77	15.74	<0.001
Wth.	47	13.39		

The F-ratio of this analysis of covariance indicated that the difference between the two group means for the comprehension part of the posttest results was significant at a level smaller than 0.001. The adjusted means for the comprehension part of the posttest are shown in Table 13. These observations show that the experimental group mean for the comprehension part of the posttest was significantly higher than that of the control group.

Hypothesis 5, that there is no significant difference between the two groups in the results of the

comprehension part of the posttest, must be rejected.

TABLE 13

ADJUSTED MEANS: POSTTEST, COMPREHENSION PART

	Raw Score	Percent
Experimental group	18.51	63.82%
Control group	14.41	49.69%

Hypothesis 6 Test

Hypothesis 6 stated that there is no significant difference between the mean scores of the two groups for that part of the posttest that was classified as application.

This hypothesis was tested in the same way as the four preceding hypotheses, except that the scores used were those of the part of the posttest that was classified as application.

The adjusted results of the analysis of covariance for the application part of the posttest are shown in Table 14.

The F-ratio of this analysis of covariance indicated that the difference between the two group means for the application part of the posttest results was significant at the 0.004 level. The adjusted means for the application

TABLE 14

ADJUSTED ANALYSIS OF VARIANCE: POSTTEST, APPLICATION PART

Source	D.F.	Mean Sq.	Adj. F	Level of Sign.
Grp.	1	177.35	9.25	0.004
Wth.	47	19.16		

part of the posttest are shown in Table 15. These observations show that the experimental group mean for the application part of the posttest was significantly higher than that of the control group.

TABLE 15

ADJUSTED MEANS: POSTTEST, APPLICATION PART

	Raw score	Percent
Experimental group	22.12	61.44%
Control group	18.36	51.00%

Hypothesis 6, that there is no significant difference between the two groups in the results of the application part of the posttest, must be rejected.

Hypothesis 7 Test

Hypothesis 7 stated that there is no significant difference between the mean scores of the two groups for that part of the retention test that is classified as knowledge.

This hypothesis was tested in the same way as the five preceding hypotheses, except that the scores used were those of the part of the retention test that was classified as knowledge.

The adjusted results of the analysis of covariance for the knowledge part of the retention test are shown in Table 16.

TABLE 16

ADJUSTED ANALYSIS OF VARIANCE: RETENTION TEST, KNOWLEDGE PART

Source	D.F.	Mean Sq.	Adj. *F*	Level of Sign.
Grp.	1	200.93	23.05	<0.001
Wth.	47	8.72		

The *F*-ratio of this analysis of covariance indicated that the difference between the two group means for the knowledge part of the retention test results was significant at a level smaller than 0.001. The adjusted means for

the knowledge part of the retention test are shown in Table 17. These observations show that the experimental group mean for the knowledge part of the retention test was significantly higher than that of the control group.

TABLE 17

ADJUSTED MEANS: RETENTION TEST,
KNOWLEDGE PART

	Raw score	Precent
Experimental group	14.33	75.42%
Control group	10.31	54.26%

Hypothesis 7, that there is no significant difference between the two groups in the results of the knowledge part of the retention test, must be rejected.

Hypothesis 8 Test

Hypothesis 8 stated that there is no significant difference between the mean scores of the two groups for that part of the retention test that is classified as comprehension.

This hypothesis was tested in the same way as the six preceding hypotheses, except that the scores used were those of the part of the retention test that was classified as comprehension.

The adjusted results of the analysis of covariance for the comprehension part of the retention test are shown in Table 18.

TABLE 18

ADJUSTED ANALYSIS OF VARIANCE: RETENTION TEST
COMPREHENSION PART

Source	D.F.	Mean Sq.	Adj. F	Level of Sign.
Grp.	1	100.27	8.58	0.005
Wth.	47	11.69		

The F-ratio of this analysis of covariance indicated that the difference between the two group means for the comprehension part of the retention test results was significant at 0.005 level. The adjusted means for the comprehension part of the retention test are shown in Table 19. These observations show that the experimental group mean for the comprehension part of the retention test was significantly higher than that of the control group.

Hypothesis 8, that there is no significant difference between the two groups in the results of the comprehension part of the retention test, must be rejected.

TABLE 19

ADJUSTED MEANS: RETENTION TEST, COMPREHENSION PART

	Raw score	Percent
Experimental group	10.76	56.63%
Control group	7.92	41.68%

Hypothesis 9 Test

Hypothesis 9 stated that there is no significant difference between the mean scores of the two groups for that part of the retention test that is classified as application.

This hypothesis was tested in the same way as the seven preceding hypotheses, except that the scores used were those of the part of the retention test that was classified as application.

The adjusted results of the analysis of covariance for the application part of the retention test are shown in Table 20.

The *F*-ratio of this analysis of covariance indicated that the difference between the two group means for the application part of the retention test results was significant at a level smaller than 0.001. The adjusted means for the application part of the retention test are shown in Table 21. These observations show that the experimental

group mean for the application part of the retention test was significantly higher than that of the control group.

TABLE 20

ADJUSTED ANALYSIS OF VARIANCE: RETENTION TEST, APPLICATION PART

Source	D.F.	Mean Sq.	Adj. F	Level of Sign.
Grp.	1	235.46	17.81	<0.001
Wth.	47	13.22		

Hypothesis 9, that there is no significant difference between the two groups in the results of the application part of the retention test, must be rejected.

TABLE 21

ADJUSTED MEANS: RETENTION TEST, APPLICATION PART

	Raw Score	Percent
Experimental group	15.05	68.41%
Control group	10.71	48.68%

Hypothesis 10 Test

Hypothesis 10 stated that there is no significant difference between the means of the two groups in the time spent by students learning the basic electrical theory either by programed instruction or by conventional classroom presentation.

Table 22 shows the mean and the range of time used in programed instruction (experimental group) and in conventional instruction (control group) to cover the same basic electrical theory.

TABLE 22

COMPARISON OF TIME USED

	Mean (hrs.)	Range (hrs.)
Experimental group	31.29	23.76 - 46.43
Control group	54.78	40.00 - 77.50

The _t_ test indicated that the difference in time was significant at the 0.001 level.

These observations show that the mean time spent in instruction of basic electrical theory was significantly less for the experimental group than that for the control group.

Hypothesis 10, that there is no significant difference between the two groups in the time spent in instruction, must be rejected.

Hypothesis 11 Test

Hypothesis 11 stated that the attitude toward the programed material of the students learning electrical

theory by programed instruction is not significantly different from the attitude of a hypothetical population of unbiased subjects.

The attitude questionnaire tested each of eight attitude concepts by one positive and one negative statement. The student was asked to check one of: "strongly agree", "agree", "no opinion", "disagree", and "strongly disagree" for each of the sixteen statements. For the positive statements the responses were given a value of 5, 4, 3, 2, and 1 respectively. For the negative statements the responses were valued in the opposite order from 1 to 5. A population of unbiased subjects would score an average value of 3 (no opinion) for each statement, and an average of 6 for each concept tested. The average unbiased score for the total questionnaire would be 48. A higher score for the experimental group would indicate a more positive attitude toward the programed material.

The results of the application of the questionnaire to the experimental group are shown in Table 23. N was twenty-five. A one-sample $\underline{t}$ test was used to determine the significance.

Hypothesis 11, that there is no significant difference in student attitude toward programmed instruction between the experimental group and a population of unbiased subjects, must be rejected. The experimental group had a significantly more positive attitude.

TABLE 23

STUDENT ATTITUDE TOWARD PROGRAMED INSTRUCTION

	Score	Average	Significant	
			.05	.01
General effectiveness (as viewed by the student)	176	7.06		*
Time to learn (as viewed by the student)	175	7.00	*	
Understanding (as viewed by the student)	160	6.39		
General preference	165	6.59		
Interesting (less boring)	156	6.24		
Better concentration	177	7.09	*	
Easier learning	166	6.64	*	
Feeling of accomplishment (reinforcement)	175	7.00		*
Total	1350	53.9	*	

CHAPTER 5

SUMMARY AND CONCLUSIONS

Chapter 5 will summarize and discuss the results of this study which investigated the effectiveness of a set of programed instructional materials for basic electrical theory. Also discussed are some related problems that were observed during the experiment. In addition attention is directed to an area that deserves further study.

Summary and Discussion of Results

In the introduction to Chapter 1 it was stated that the most important advantage of programed instruction is that its use can facilitate individual student progress and individualized instruction. This advantage alone would justify the use of programed instruction, even if it is not better in general effectiveness than conventional instruction.

The set of programed instructional materials investigated in this study appear to be superior in all factors that are generally included in the definition of effectiveness for a teaching method. It would, therefore, seem justified to recommend its use where applications are similar to the ones described in this study.

The discussion of the results should start with the experimental design which attempted to test all major

factors that various authorities would include in the definition of effectiveness. There were some variations in the literature that was reviewed, however, it would seem that measures of achievement, retention, comprehension, application, time, and attitude would satisfy most of the recommendations. The experiment was designed to test all these factors. The experimental design also tried to create a situation that would resemble the future practical use of the programed material as closely as possible. In this study the programed instructional material was integrated with student experiments, problem assignments, textbook references, and demonstrations.

The statistical analysis evaluated achievement by testing hypotheses 1 and 2; retention was tested by hypothesis 3; the program's performance with regard to knowledge, comprehsnion, and application was tested by hypotheses 4 to 9; time and attitude were tested by hypotheses 10 and 11 respectively.

Hypothesis 1 was formulated to test the question how well the individual units of programed instructional material achieved the learning objectives for which they were designed. The standard that 75% of all students must complete 75% of the items on each subtest correctly was chosen because the programed material was not intended to produce mastery of each concept without any further instruction.

For six of the twenty-two subtests this standard was

not reached. However, the averages of all items for each student showed that 92% of the students completed 75% or better of the total subtest items correctly.

Since no comparison was used for the first hypothesis, it is not possible to determine whether this outcome is statistically significant. It must be left to the future user to decide whether the results are acceptable for his purpose. The results should also be reviewed in conjunction with the actual subtests (Appendix B).

Hypotheses 2 and 3 compared the learning achievement and the retention of students who used the programed material with the learning achievement and retention of students learning by conventional teaching methods. The statistical analysis showed that the experimental group performed significantly better both in achievement and in retention.

To test the effectiveness of the programed material with respect to knowledge, comprehension, and application, the items of the posttest and of the retention test were divided into these three classes. Bloom (1956) in his *Taxonomy of Educational Objectives: Cognitive Domain* classified knowledge, comprehension, and application in ascending order, and the higher classifications are sometimes assumed to be more difficult to learn.

Hypotheses 4, 5, and 6 compared the achievement of the experimental group with that of the control group in

each of the knowledge, comprehension, and application classes of the posttest. The means of the experimental group were significantly higher in all three classifications.

Hypotheses 7, 8, and 9 compared the retention of the two groups in the three classes of the retention test. Again, the experimental group means were significantly higher in all three classifications.

The results of the hypothesis 10 test showed that the time spent in programed instruction was significantly less than the time spent in conventional classroom instruction covering the same concepts of basic electrical theory.

It may be argued that, because students in the experimental group spent less time in programed instruction, they had more time available for the supplementary instruction and this would influence the total learning achievement and retention. However, the faster students were allowed to go on beyond the basic concepts covered by this study, so that there was in fact a saving of time.

The results of the test for hypothesis 11 showed that the student attitude toward programed instruction is significantly more positive than that of a hypothetical unbiased population.

The attitude questionnaire was constructed from a matrix that included eight different concepts (see Appendix B). When the total result is broken down into these eight

concepts (Table 23, page 61), it can be seen that the students' perception of greater efficiency and less time required for the programed material agrees with the actual findings.

In keeping with most recommendations made in the literature, no attempt was made to combine all the factors of effectiveness into one index. It must be left to the individual user to determine the relative importance of each factor in his situation. However, since achievement, retention, time, and attitude were significantly better for the experimental group, and since the higher achievement and retention was observed in all of the classifications of knowledge, comprehension, and application, it can safely be said that the programed instructional material evaluated in this study was more effective than conventional classroom instruction as it was used in this experiment.

Other Problems

There were some problems related to the use of programed instructions that were observed in this study, and that could possibly reoccur in similar applications of programed material. These problems were primarily connected with the varying time that different students used to work through the programed material and with the individual progress made possible by the use of programed

instruction. Some students were so conditioned to work being done and handed in at a date set by the teacher that it was necessary to give them such dates, at least for the beginning of the course; however, such time limits were taylored to suit the individual student's ability. Other students looked for some time norm that seemed acceptable to their peers.

Perhaps the biggest problem arose from the insistence of the school system that a certain course must take a given number of hours for all students. This meant that some meaningful and relevant additional learning situations had to be found for the faster students, while some very slow students were unable to finish all parts of the course. This preset time factor also discouraged some of the more able students from completing their work as fast as they could.

Once the students and the teacher overcome these initial problems, they will find this method of instruction more rewarding. The student attitude toward the programed material was indiciated by the results of the attitude questionnaire. Most teachers would also find the use of programed material more satisfying, as they will feel that they have better opportunities to deal more directly and more effectively with different problems that individual students may have.

Suggestions for Further Study

There is one issue that would deserve some further investigation. It seems puzzling that programed instruction is not more widely used. This study, as well as many other ones, show that programs can be as effective and in many cases more effective than other teaching methods. This study also shows that it is possible -- even though very time consuming -- for a teacher to prepare a program that suits the needs of his students and his course. It is also evident that programed instruction makes possible -- and is in some cases essential -- to put into practice several of the educational concepts that are advocated by contemporary educationists. Such concepts as individualized learning, individual and continuous student progress, self-initiated and independent study, and several others can be made possible by programed instruction.

Several reasons could be postulated for the reluctance of most educators to use programed instructional materials more extensively, but it is likely that a combination of factors causes the failure to put this method to more widespread use. However, any such assumptions must be investigated using a more systematic approach.

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APPENDIX A

SAMPLES OF PROGRAMED INSTRUCTIONAL MATERIALS

INSTRUCTIONS

You should have no difficulty working through this programed course for basic electrical theory. Each unit is divided into a number of "frames". Each frame will take you a small step in your learning. Each frame will also have one, or sometimes more than one, blank space. You are required to fill in the blank space and therby complete the statement. Read each frame through to the end and look at the diagram, whenever there is one, before you make your response by completing the __________ space.

After you have completed the response in frame #1, you go on to frame #2. You will find frame #2 not below frame #1, but on the top of the next page. The following frame will always be on the next page until you reach the last page of the unit. There you will be told to go back to the starting page of the unit and you will find the next frame in the next lower space.

At the beginning of frame #2 you will find in parentheses (   ) the correct response, or responses, that you should have given in frame #1. Your response need not always be exactly the same wording, as long as it has the same meaning as the one given. If your response was ____________ and the one given in the parentheses is (twice), your response is, of course, equally correct. Looking ahead for the correct response will not facilitate the best learning.

If the response you gave in one frame is different from the one given ahead of the next frame, go back and try to find out why ou made this mistake, and correct your response. You will find that you get only a few incorrect responses. If you get one quarter or more of the responses wrong, you should be more careful in reading the information given in the frames.

Speed is not important in completing each unit, but once you have started one unit, you should try to complete it without interruption.

In this programed material some concepts or problems in one frame may relate to information given in the foregoing frame. Do not change the order in which you work through the material from that indicated by the numbering of the frames.

UNIT 1

ELECTRICITY AND MATTER

This first unit is a brief introduction into the smallest buildign block of all chemical elements, the atom. Every chemical element is made up of atoms, and all material or matter is made up of one or more chemical elements. All matter is therefore made up of atoms. This unit will show how electrical forces are necessary to keep atoms, and thereby all physical matter, together.

Each atom is made up of a core or nucleus and a number of electrons that move around this nucleus. This first unit will introduce you to the atom and will describe some features of the nucleus. The second unit will cover the behavior of electrons in conductors and insulators.

Atoms are incredibly small and cannot be seen. The model of the atom as it is generally accepted is therefore, strictly speaking, a theory. This theory however, works so well in all respects that we can safely accept it as fact.

This short introduction into the structure of matter will enable you to better understand other concepts of electricity which are covered in later units.

1. Working through these programmed instructions you should always compare your answer(or answers) with the answer(s) given at the begin of the next frame. From the instruction page you remember that the second frame is not below the first one, but on the ____________ page. This means that the answers to this first frame are found on page number ____. (If you did not read the instruction page, you better do it now.)

10. (nucleus) [If this is the second frame you work through, then you are not following the instructions. Read the instruction page!]
Even though the electron in the hydrogen atom does not follow an exactly circular path, it will normally be a definite distance away from the nucleus. This distance is determined by the attracting force between the __________ (positive/negative) electron and the ___________ (positive/negative) nucleus.

19. (twice) Because of the importance that this "heavy hydrogen" atom has in nuclear physics, it has been given a separate name: "deuterium". Deuterium is chemically the same as ______________ , but physically it is _____________ as heavy as hydrogen.

28. (13)(14) Sodium has an atomic number of 11 and an atomic weight of 23. This information tells us that the sodium nucleus contains _______ protons and ______ neutrons.

37. (repel) By now you might be wondering about the positive charges in the nucleus. In all nuclei (except the hydrogen nucleus) there is a number of positive charges close together. Since the protons in a nucleus have all positive elctrical charges, they should ____________ each other. This should result in the nucleus being pushed apart. This happens only in the radioactive elements and in the radioactive isotopes of elements. Almost all natural elements are stable. The number of neutrons in the nucleus has some influence on whether the element is stable or radioactive.

2. (next)(3) Electrical theory can be learned in a very logical step by step manner. You need to understand the basic concepts for further study of electrical theory, and you need the theoretical background for experiments and practical work. You can check whether you understand the material by comparing your answers with the ones given in the ___________ ______________ .

---

11. (negative)(positive) Because the nucleus of the hydrogen atom has one positive electrical charge (+1), and the electron has one negative electrical charge (-1), the total electrical charge of the complete hydrogen atom is _____________ .

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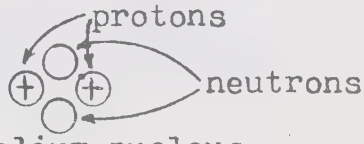
20. (hydrogen)(twice) the next more complex chemical element is helium. Its nucleus contains two protons and two neutrons. The two positive protons in the nucleus can hold _______ electrons to the atom.



helium nucleus

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29. (11)(12) When two atoms have a different atomic number, they hold a different number of electrons and must have __________________ chemical charateristics.

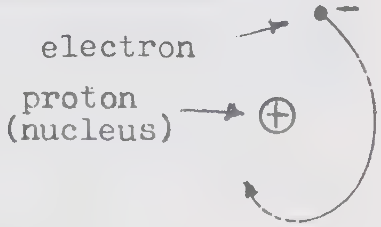
---

38. (repel) So far we have learned that the protons and the neutrons are found in the _________________ of the atom, and the _________________ move around the nucleus.

3. (next page/next frame) It should normally not be too difficult to get this answer. If a frame really dosn't make any sense to you, even after you read it twice, you may want to look at the answer; this may clear the confusion. However, you should not just look up the answer so that you have something to fill in the blank. A person doing that will not learn anything, but would only waste his time. He must obviously be some kind of a _________ .

---

12. (zero/neutral) The positively charged particle that makes up the nucleus of the hydrogen atom is called a proton. We can, therefore say that the hydrogen atom is made up of one _________________ and one _________________ .



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21. (two) Each proton and each neutron has a unit weight of one. Helium has two protons and two neutrons in its nucleus. Neglegting the weight of the electrons, the atomic weight of helium is _______________ .

---

30. (different) The atomic number for copper is 29. Hence, any atom having 29 protons and 29 electrons must be a _______________ atom.

---

39. (nucleus)(electrons) The proton has a ________________ electrical charge and a unit weight of ____________ . The neutron has ______________ electrical charge and a unit weight of ___________ .

4. (You said it, and I won't disagree) Enough of the pep talk, let's invetigate how electricity is present in every piece of material.
All material (or matter) is made up of chemical elements. Sometimes the material consists only of one element, such as in copper or iron. Sometimes two or more elements are combined into a chemical compound such as in water or in sugar. Water can be chemically divided into hydrogen and oxygen. Hydrogen and oxygen however, can not be broken down any further--at least not by chemical means. They are chemical ____________________ .

---

13. (proton)(electron) or (electron)(proton) The fact that the proton has a positive electrical charge and the electron has a negative electrical charge is not the only difference between the two particles. When we compare the weight of the proton with that of an electron, we find that the weight of the electron is so small that it can be neglected in most calculations of atomic weight. We will get a very close measure of the weight of the hydrogen atom by determining the weight of only the ____________________ .

---

22. (four) The weight of the electron, when compared to the weight of protons and neutrons, is so small that it can be neglected. Therefore, the unit weight of an atom (or the atomic weight of an element) is determined by the addition of the number of ____________________ and the number of ____________________ in the nucleus of an atom.

---

31. (copper) Most carbon nuclei (or nucleuses, which is also a correct plural form of nucleus) contain six protons and six neutrons. These carbon atoms must have the atomic number of ______, and the atomic weight of ________.

---

40. (positive)(one)(neutral/no)(one) The electron has a ________________ electrical charge, and when compared to the proton or neutron its weight _________________________ .

5. (elements) The smallest building block of a chemical element is the atom. Carbon is a chemical element and its smallest building block is the carbon atom. Copper is another chemical element and its smallest building block is the ____________ atom.

---

14. (nucleus / proton) When we express the weight of a proton in ounces or in grams, it would be an extremely small weight, but when we talk about the weight of a certain atom we use as a unit the weight of one proton. We say that the proton has a unit weight of one. The hydrogen atom consists of one proton and one electron. Because we neglect the weight of the electron, we say that the unit weight of a hydrogen atom is ________ .

---

23. (protons)(neutrons) or (neutrons)(protons) The chemical charateristic of an atom is determined by the number of electrons that the atom holds when it is electrically balanced. When an atom has a different number of electrons than another one, it is chemically ______________ from that other atom.

---

32. (6)(12) About 1.1% of all carbon nuclei contain seven neutrons besides the normal six protons. These atoms, then, have the atomic number ______ and the atomic weight _______ .

---

41. (negative)(can be neglected/very small) In an electrically balanced atom the number of electrons that move around the nucleus must equal the number of _________________ in the nucleus.

6. (copper) Just like chemical elements are different from one another, the atoms that make up these different elements must be _______________ from one another.

---

15. (one) The proton is not the only particle present in the nuclei of atoms. There is another particle that has no electrical charge; it is neutral and is therefore called a neutron. The weight of the neutron is the same as that of a proton. The neutron has an atomic unit weight of ______.

---

24. (different) The chemical characteristic of an atom is determined by the number of electrons it has. Since the number of electrons and protons in an atom is equal, the chemical characteristic of an atom is also determined by the number of _______________ in the nucleus.

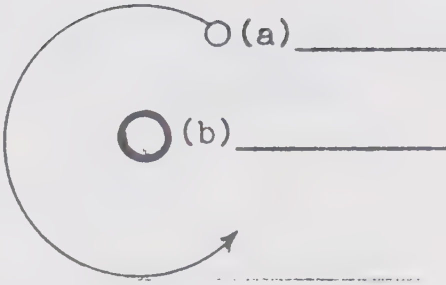
---

33. (6)(13) Atoms which have the same atomic number, but a different atomic weight are called isotopes. Most chemical elements have a number of isotopes. Because the isotopes of one element have the same atomic number, they cannot be chemically _______________ .

---

42. (protons) The electrons are held by the nucleus, because opposite electrical charges _________________ .

7. (different) The simplest atom in existence is the hydrogen atom. It has only two parts, the nucleus in the center of the atom and the electron which moves around the nucleus at a certain distance. (Put the names of the two particles of the hydrogen atom on the lines in the sketch.)



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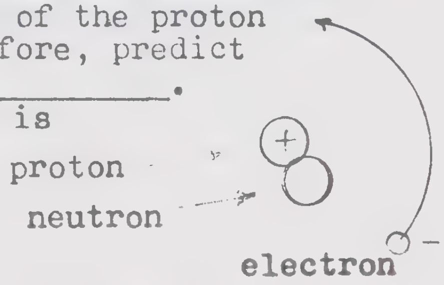
16. (one) There is a very interesting variation of the hydrogen atom. It has one proton and one neutron in its nucleus. We know the atomic unit weight of the proton as well as of the neutron, and can therefore, predict that the atomic weight of this atom is ________. This variation--or isotope-- of hydrogen is called heavy hydrogen.



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25. (protons) The number of protons (which corresponds to the number of electrons) in an atom is represented by the atomic number of that atom. Iron has the atomic number 26. We know therefore, that the iron atom has ______ protons in its nucleus, and that the complete and electrically balanced atom has _______ electrons.

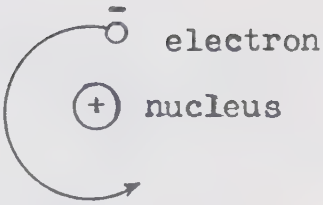
---

34. (different) When you look up the element germanium in a table of chemical elements, you find that it has an atomic number of 32 and an atomic weight of 72.6. This does not mean that the germanium nucleus contains 40.6 neutrons. The fractional number in the atomic weight is due to the fact that germanium as it occurs in nature consists of a mixture of isotopes, some having 38, 40, 41, 42, and 44 neutrons. It is not possible for a single atom to contain only a part of one neutron, or for that matter, a part of a proton or electron, because these particles cannot be ____________ .

---

43. (attract) You have also learned that the atomic number tells us how many ________________ there are in the nucleus, and how many electrons the atom can hold when it is electrically balanced. This in turn determines the ________________ characteristic of that atom.

8. ((a)electron, (b)nucleus) The nucleus of the hydrogen atom has a positive electrical charge, and the electron has a negative electrical charge of equal strength. Because a positive and a negative electrical chargeswill attract each other, there will be a force of ______________ between the nucleus and the electron.



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17. (two) There is only one proton in the nucleus of this atom. To make this atom electrically balanced, there must be ________ electron(s) moving around the nucleus.

---

26. (26)(26) Atomic weight is determined by the total sum of protons and neutrons in the nucleus. The atomic weight of aluminum is 27. This tells us that the sum of the protons and the neutrons in the aluminum atom is ________ .

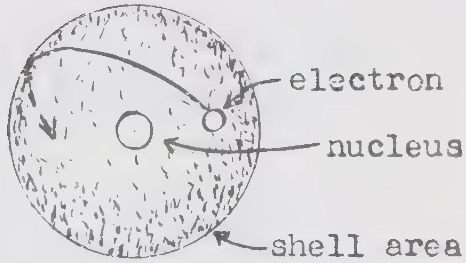
---

35. (divided/split) Isotopes differ only in the number of neutrons they have in the nucleus but not in chemical charateristics. The deuterium atom contains one extra neutron besides the single proton of the hydrogen atom. Deuterium is a(n) ________________ of hydrogen.

---

44. (protons)(chemical) The atomic weight tells us the sum of the ______________ and ___________________ in an atom. When we deduct the atomic number (the number of protons) from the atomic weight, we find the number of ____________ in the nucleus.

9. (attraction) The electron of the hydrogen atom moves around the ______________ . But this does not mean that it moves in a definite circular path. It may at a certain time be found anywhere in a spherical area around the nuleus. This area can be compared to a shell. (Return to page 2.)



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18. (one) The chemical characteristic of an atom depends on the number of electrons that the atom can normally hold. This atom has only one electron and it behave chemically like hydrogen. But it has one neutron besides the one proton in its nucleus, and it is therefore, __________ as heavy as the normal hydrogen atom. (Return to page 2.)

---

27. (27) The atomic number of aluminum is 13. This tells us that there are ______ protons in the nucleus, and because the atomic weight of aluminum is 27, we can also conclude that there are ________ neutrons in the nucleus. (Remember, 27 is the sum of the protons and neutrons.) (Return to page 2.)

---

36. (isotope) We have mentioned that unlike (or dissimilar) charges attract, and it seems reasonable to conclude that like (or similar) charges ____________ . (Return to page 2.)

---

45. (protons)(neutrons) in any order (neutrons) It is believed that there are a number of other particles that can sometimes be found in an atom. These particles differ in weight, size, and electrical charge from the three common ones that we have dealt with, which were the ________________ , the ___________________, and the ___________________. We can, however, understand electrical theory without a detailed knowledge of these not so common particles.

Answer to 45: (proton)(neutron)(electron) in any order

UNIT 11

SIZES, RESISTANCE, AND TEMPERATURE COEFFICIENT OF WIRES

In this unit you will learn how diameter and cross-section area--the area available for current flow--of wires are measured. The cross-section area is usually expressed in circular mils (CM). This CM area will be compared to the wire sizes as designated by the American Wire Gauge (AWG).

Resistance of a wire can be calculated when the CM area, the length, and the resistivity of the material is known. The resistivity--the resistance of a material for a conductor of standard length and standard diameter--changes with temperature. The temperature coefficient can be used to calculate this change.

1. The logical way to specify a certain wire size would be to measure the diameter. Since the inch is too large a measure for most wires, a smaller unit, the mil is commonly used to measure the diameter of wires.

$$1 \text{ mil} = \frac{1}{1000} \text{ inch}$$

We can, of course also say that

1 inch = (complete the equation.)

---

9. (900)(6300) We can also find the diameter that is required to give a certain CM area.

$$\text{diameter in mils} = \sqrt{\text{CM area}}$$

If a conductor of 10,000 CM is required, we know that it must have a diameter of _______ mils, which is the same as _______ inch.

---

17. (less than) In fact it is rated at 40 amps.

Another fact of interest is the resistance of a wire of a given length, size, and material. It seems obvious that resistance and length are directly proportional. When 200 ft of #12 copper wire have 0.318 ohm resistance, then 1000 ft of the same wire must have ________ ohms resistance.

---

25. (0.1) One more before you forget how: A copper wire with length=500ft and area=2600 CM has a resistance of _______ ohm(s). (I hope you don't get the notion that all practical problems have values that are that easy to compute.)

---

33. (.004) Let's try one more: A copper coil in a motor has a "cold" (20° C) resistance of 25 ohms. During the operation the temperature of the motor rises to 60° C. The resistance at that temperature is ________ ohms.

2. (1000 mils--note the spelling: one l in mil) The diameter of a certain wire is .22 inch. We multiply this value by 1000 to get the diameter in mils. This wire would have a diameter of ________ mils.

---

10. (100)(0.1) Now that you know how to handle mils and circular mils, it seems appropriate to tell you that most wire sizes are normally not designated by either one of these measurements. The wire sizes that are commonly used are those of the American Wire Gauge (AWG) (AWG was formerly known as the Brown and Sharp Gauge, B&S). In the AWG system the larger wire will have the smaller number, and the smaller wires have the larger numbers. A number 14 wire will have a diameter that is ______________ (larger/smaller) than that of a number 10 wire.

---

18. (1.590) On the other hand, resistance and circular-mil area are inversely proportional. 1000 ft of #10 copper wire, with 10,000 CM have 1.00 ohm resistance. 1000 ft of a wire with 20,000 CM must have ________ ohm resistance (because there is more room for current to flow).

---

26. (2) If you need to find the length of a certain wire that would be required to make a certain resistance, you can transpose

$$R = \frac{kl}{CM}$$ to solve for l. (length)

You would multiply each side by $\frac{CM}{k}$ to get

$R\underline{\qquad\qquad} = \frac{kl\qquad\qquad}{CM}$ (complete the equation)

We can now cancel R and CM in the fraction on the right to get:

________ = l or reversed: l = ________ .

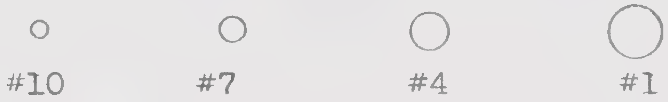
---

34. (29) We can also determine the temperature change in a conductor by measuring the change in resistance and dividing this change by $\alpha \times R_{20}$. A copper relay coil with R_{20} of 200 ohms, operates for some time. When it is measured again, the resistance has increased by 16 ohms to 216 ohms. The temperature increase must be ________ centigrade, and the operating temperature of the coil is ________ C.

3. (220) A wire with the diameter of 0.078 inches would measure ________ mils in diameter.

---

11. (smaller) There is some relationship between the AWG sizes and the CM area. A number 10 AWG wire has very close to 10,000 CM, and for every third lower AWG number the CM area is doubled. A number 7 wire would have ________ CM; a number 4 wire would have ________ CM, and so on.



Actual size of bare (uninsulated) solid (not stranded) conductors.

---

19. (0.50) The third factor affecting the resistance of a wire is the material that it is made of. Copper is one of our best conductors; only silver is slightly better. However, silver is rarely used, because it is too expensive. Aluminum has a resistivity somewhat higher than copper (which means that it is not as good a conductor), but because it is light in weight it is often used for overhead line wires. Iron and special resistance wires such as nichrome, chromel, etc. have resistivities several times higher than copper. The material most commonly used for wires are ____________ to some extend ____________, with silver being too expensive for general use.

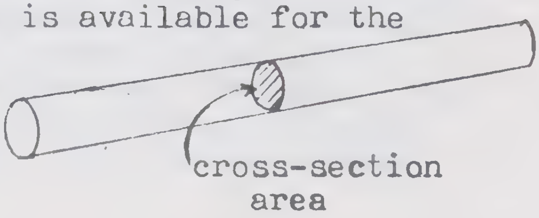
---

27. ($\frac{R\ CM}{k} = \frac{\cancel{k}\ l\ \cancel{CM}}{\cancel{CM}\ \cancel{k}}$) ($l = \frac{R\ CM}{k}$) Suppose you have to make a wire-wound resistor of 10 ohms using nichrome wire with k=600 and a cross-section area of 1200 CM. You would require ______ft of wire for this resistor. (Do your calculations right here.)

---

35. (20^0)(40^0) The temperature coefficient is based on an original temperature of 20^0 centigrade. However, the coefficient may also be used with reasonable accuracy when the starting temperatures are somewhat higher or lower. Only in extreme temperature changes is the temperature coefficient no longer accurate. The tungsten filament wire of an incadescent lamp operates at temperatures above 2000^0 C. All we can say in that case is that such a very high temperature increase must result in a __________ __________ resistance increase.

4. (78) The amount of current that a wire can carry is determined by the cross-section area that is available for the electron movement. If we would measure the diameter in inches, then the unit for the measurement of the cross-section area would be the __________ __________ .



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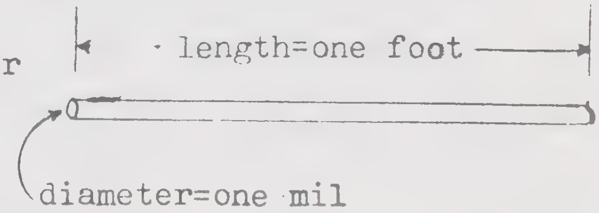
12. (20,000)(40,000) On the other hand for every third higher AWG number the CM area is divided by two. A #13 wire would have ________ CM, and a #16 wire would have ________ CM. These figures, however, are only approximate values; for exact values it is best to consult a table of wire sizes.

---

20. (copper)(aluminum) The resistivity of materials can be given as the ohms-per-mil-foot resistance. This would be the resistance of a conductor with a diameter of ________ ________ and a length of _______ _______ . (A conductor with one mil diameter would be cosiderably smaller than a human hair, and indeed difficult to manufacture and to handle.)



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28. (20) The resistivity (k) is usually given for room temperature, which is considered to be 20° centigrade(or 68° F). The resistance of most metals increases slightly when the temperature goes up. The resistance of a transformer coil is measured at room temperature and then again after the transformer has been operating for some time and its temperature has increased. The second measurement will be slightly ________________ .

---

36. (very high) In fact the resistance of most filament lamps is about 10 to 15 times higher when the lamp is operating (hot) than the cold resistance.

Let's review what we learned in this unit: The mil is used to express the diameter of wires and is equal to _______ inch. The circular mil, CM, is used to express the cross-section area of wires and is found by simply taking the ______________ in mils to the _______________ .

5. (square inch) It seems logical to use the square mil for the cross-section area of smaller conductors. However, another unit the circular mil (CM) is used for most conductors. First of all it is important to remember that the square mil is not normally used to measure the cross-section area of wires. The unit that is commonly used for this measurement is the ____________ _____ .

13. (5000)(2500) A #1 AWG wire is more than ¼ inch in diameter while a #40 wire is smaller than a human hair. A number 1 wire can carry over 100 amperes, but this is not sufficient for many modern applications and the next larger wire sizes were designated as 0, 00, 000, and 0000.(Also called: one-naught, two-naught, three-naught, and four-naught.) After that the system switches back to CM measurements with wire sizes of 250,000 CM, 300,000 CM, and up. A number 000 (or 3/0) wire would be ____________ (larger/smaller) than a #3 wire and __________ than a 400,000 CM wire.

21. (one mil)(one foot) The ohms-per-mil-foot resistance for silver is 9.8, for copper it is 10.4, for aluminum it is 17, for iron 75, for nichrome 600, etc. The important one to remember is the one for copper which is ______ .

29. (higher) We can calculate the resistance increase by using the temperature coefficient. The temperature coefficient for copper is .004. That means that for every degree centigrade temperature increase a resistance of one ohm would increase by 0.004 ohms. When the temperature of a copper coil of one ohm resistance is increased by 20° C, the resistance would increase by ______ ohms and the new temperature would be ______ ohms. (Sometimes the symbol α (alpha) is used for the temperature coefficient and a value of 0.00393 is also used for copper; however, 0.004 gives results that are accurate enough for our purposes.)

37. ($\frac{1}{1000}$)(diameter)(square) The Americam Wire Gauge (AWG) is a numbering system where the smallest number stands for wire sizes with the __________ CM area and vice versa. The current carrying capacity of wire depends, of course, on the ______________, but is also affected by the temperature rating of the insulation and by the location and usage of the wire. (Wires that are well ventilated-- in free air-- can carry higher currents. When many wires are enclosed in a conduit or cable, or when the surrounding air is hot, the ampacity is less.)

6. (circular mil) The circular mil (CM) is particularly easy to calculate from the diameter of any round conductor.

$$\text{Area in CM} = (\text{diameter in mils})^2$$

All we need to do to find the circular mil area of a round wire, is to measure the diameter in __________ and to take this number to the ______________ .

14. (large)(smaller) To avoid writing long numbers a size such as 250,000 CM is commonly referred to as 250 MCM. A 500,000 CM conductor would be called 500 MCM etc. We see that in designating large wire sizes the first M in MCM stands for ________. (And that after painfully instructing you in Unit 8 that a capital M stands for 1,000,000.)

22. (10.4) To calculate the resistance of a given wire we use:

$$R = \frac{k \times l}{CM}$$

k is the ohms-per-mil-foot resistivity (10.4 for copper); l is the length in feet; and CM is the circular mil area. The formula is easy to remember because we know that ohms-per-mil-foot resistivity (k) and length (l) are ______________ proportional to R, while the CM area is ________________ proportional to R.

30. (0.08)(1.08) When we increase the temperature of a five ohm copper coil by 20° C, we get an increase of 5x20x0.004 ohms or _______ ohms. A common mistake is to use this increase as the final resistance value. However, this increase must be added to the original resistance. The new resistance value in our case would be ________ ohms.

38. (larger)(wire size or CM area) The formula to find the resistance of wires is easy enough to remember as long as we understand that R is directly proportional to the ohms-per-mil-foot resistivity (k) and the lenght (l), and that R is inversely proportional to CM area. The formula is:

R = ____________

7. (mils)(square) A wire with the diameter of 70 mils will have a cross-section area of ________CM. This was easy. Compare it with the computations necessary for square mil. You would have to take the radius (35 mils) to the square, and then multiply by 3.14 (π). The result would be 3846.5 square mils, a number somewhat smaller than that found for the circular mils.

15. (1000) Different wire sizes can carry different amounts of current. However, the current-carrying capacity or ampacity of wires is also determined by the temperature rating of the insulation, and the location and usage of the wire. The same wire has a higher ampacity in free air--where heat can get away faster--than when enclosed in a cable or conduit (pipe). In general however, a larger wire has a _______________ _______________________ .

23. (directly)(inversely) Well, if it is so easy, why don't you write it down once more. Remember factors that are directly proportional to R must be above the fraction line, while those inversely proportional are below.

R = ____________

31. (0.4)(5.4) If you like formulas you can put the whole operation into one (difficult to remember) formula:

$$R_x = R_{20} x \alpha x (T_x - T_{20}) + R_{20}$$

R_x is the resistance at the new temperature and R_{20} is the temperature at ______ centigrade. (T_x - T_{20}) is the temperature ____________, again in centigrades and α is the temperature coefficient. When T_x is lower than T_{20} we have a temparature decrease and also a decrease in resistance.

39. ($R=\frac{k\ l}{CM}$) The temperature coefficient tells us the amount of resistance change for every ____________ of original resistance (at 20° C) and for every ____________________________ temparature change.

8. (4900) If a wire consists of seven individual strands (diagram) and each strand has a diameter of 30 mils, we must first find the CM area for each strand, which is ______ CM, and then multiply by seven to find the total cross-section area of the stranded conductor. The total area is ______ CM. (Return to page 2.)

stranded wire

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16. (higher ampacity) However, ampacity is not directly proportional to CM area. In larger wires the heat produced by the current cannot escape as fast, because there is a larger mass of metal to cool off. Larger wires can, therefore carry less amps per CM. A number 14 wire with thermoplastic insulation is normally rated for 15 amps when used in a cable or conduit. A number 8 wire is six numbers less, and must have about four times the CM area. But we find that a #8 wire under the same conditions is rated at ____________ (less than/more than/exactly) 60 amps. (Return to page 2.)

---

24. ($R=\frac{k \times l}{CM}$) When a copper wire is 100 ft long and has a CM area of 10,400 CM the resistance will be ________ ohms (I hope you remember k for copper, if not, look in frame 21.) (Do your calculations right here)(Return to page 2.)

---

32. (20^o)(difference or increase) You don't really need to remember a formula for the temperature coefficient, because the procedure follows a logical pattern. The temperature coefficient tells us the amount of resistance increase for every original ohm times the degree centigrade increase. But you should remember the temperature coefficient for copper which is ________. (You used it in frames 29 and 30.) Semiconductors such as germanium, silicon, etc. have a negative temperature coefficient. This means that the resistance decreases when the temperature increases.) (Return to page 2.)

---

40. (ohm)(degree centigrade) Two constants that are useful to remember are the ohms-per-mil resistivity (k) for copper which is _______, and the temperature coefficient for copper _________ .

Answers to frame 40: (10.4)(0.004 or sometimes 0.00393)

APPENDIX B

SUBTESTS, CONSTRUCTION MATRICES AND TEST INSTRUMENTS FOR PRETEST, POSTTEST, RETENTION TEST, AND QUESTIONNAIRE

Basic Electricity
Test #1
Matter and Electricity

Name: ____________________

1. The normal charge possessed by an atom is
   - A. positive.
   - B. negative.
   - C. neutral.
   - D. either positive or negative.

2. The two main particles found in the nucleus of an atom are
   - A. electrons and neutrons.
   - B. protons and positrons.
   - C. protons and electrons.
   - D. protons and neutrons.

3. The nucleus of an atom is
   - A. positively charged.
   - B. negatively charged.
   - C. neutral.
   - D. either positive or negative.

4. The particles of an atom that move around the nucleus like planets move around the sun are called
   - A. protons.
   - B. neutrons.
   - C. electrons.
   - D. positrons.

5. The proton has the following properties in an atom:
   - A. a positive charge and a unit weight of one.
   - B. a negative charge and a unit weight of one.
   - C. no charge and a weight that is so small that it can be neglected in calculations of atomic weight.
   - D. no charge and a unit weight of one.

6. The neutron has the following properties in an atom:
   - A. a positive charge and a unit weight of one.
   - B. a negative charge and a unit weight of one.
   - C. no charge and a weight that is so small that it can be neglected.
   - D. no charge and a unit weight of one.

7. Every electron has
   - A. a positive charge.
   - B. a negative charge.
   - C. a nucleus.
   - D. a miniature solar system.

8. Iron has the atomic number 26. This means that the iron atom normally contains
   - A. 26 neutrons.
   - B. a total of 26 neutrons and protons.
   - C. a total of 26 neutrons and electrons.
   - D. 26 protons and 26 electrons.

9. The element of sodium has the atomic number 11 and the atomic weight 23. From this information we can conclude that the average sodium nucleus has
   A. 11 protons and 12 neutrons.
   B. 23 protons and 23 neutrons.
   C. 23 protons and 23 electrons.
   D. 12 protons and 11 neutrons.

10. Isotopes of chemical elements have
    A. the same atomic weight, but a different atomic number.
    B. the same number of protons, but a different number of neutrons.
    C. the same number of neutrons, but a different number of protons.
    D. a different atomic number and different atomic weight.

11. Magnesium has an atomic weight of 24.31. The fractional weight .31 is caused by
    A. the average weight of several magnesium isotopes.
    B. a proton of .31 weight.
    C. a neutron of .31 weight.
    D. the additional weight of all the electrons in the magnesium atom.

12. The chemical characteristic of an element is determined by
    A. its atomic weight.
    B. its atomic number.
    C. the number of neutrons in the nucleus.
    D. the total sum of the protons and neutrons in the nucleus.

Basic Electricity
Test #2
Conductors and Insulators

Name: ____________________

1. When an atom has more than two electrons the electrons arrange themselves:
   A. all at the same distance from the nucleus
   B. in a number of different energy levels (energy bands)
   C. in the order of their electric charge (the weakest charge closest to the nucleus)
   D. all in one circular orbit

2. The electrons that are in the lowest energy level are:
   A. closest to the nucleus
   B. farthest from the nucleus
   C. of higher electron spin
   D. of lower electrical charge

3. When an atom becomes excited by heat or in some other way, one or more of its electrons:
   A. drop to levels of lower energy
   B. gain more electrical charge
   C. jump to levels of higher energy
   D. become positive

4. Which statement would best describe the shape of an electron orbital?
   A. The electron orbitals must always be circular.
   B. The electron orbitals are always perfect spheres or shells.
   C. Electron orbitals can have various different shapes and some have a directional arrangement.
   D. Electron orbitals have no definite shapes, but must hold some electrons of negative charge.

5. An electron orbital in an atom can be occupied by not more than
   A. two electrons of opposite charge
   B. two electrons of opposite spin
   C. one electron at one time
   D. six electrons moving in three different dimensions

6. In electrical terms metals are:
   A. conductors
   B. insulators
   C. electrically charged
   D. electrically inert

7. To prevent the flow of electrons, it is necessary to use:
   A. conductors
   B. meters
   C. lamps
   D. insulators

8. The characteristic that makes some materials conductors and others insulators is
   A. that conductors have more electrons than neutrons
   B. that conductors have free electrons
   C. that conductors have positive electrons
   D. that insulators have no electrons

9. Electrons in the highest energy bands of metal atoms are not very tightly held to the nucleus. They frequently jump to one of the neighboring atoms. These electrons
   A. all of B, C, and D are correct
   B. can conduct electric current
   C. are free electrons
   D. are in the conductance band

10. When a semiconductor material is heated, some electrons will move to a higher energy band. The material becomes
   A. all of B, C, and D are correct
   B. a better insulator
   C. a better conductor
   D. electrically charged

Basic Electricity
Test #3
Static Electricity

Name: ____________________

1. Static electricity is referred to as:
    - A. positive electricity
    - B. negative electricity
    - C. current electricity
    - D. electricity at rest

2. An electrostatic charge is:
    - A. both C and D are correct
    - B. neither C nor D is correct
    - C. a lack of electrons
    - D. a surplus of electrons

3. An atom of sulfur has gained one electron so that it holds 17 electrons instead of the regular 16. This atom can be called:
    - A. a balanced atom
    - B. a positive ion
    - C. a negative ion
    - D. a balanced ion

4. A positively charged body has:
    - A. no electrons
    - B. a lack of protons
    - C. a surplus of electrons
    - D. a lack of electrons

5. When a positively charged object is opposed by a negatively charged object, the outcome is:
    - A. an attractive force
    - B. a repulsive force
    - C. an increase in the charges
    - D. a build-up of current

6. The materials that can hold electric charges include:
    - A. both C and D
    - B. neither C nor D
    - C. insulators
    - D. conductors

7. When a charged object is discharged to ground it means that:
    - A. both B and C
    - B. electrons have moved to ground from the object
    - C. electrons have moved to the object from ground
    - D. protons have moved from ground to cancel the charge

8. In lightning electrons flow in the direction from
   - A. both C and D are correct
   - B. neither C nor D is correct
   - C. clouds to ground
   - D. ground to clouds

9. The area surrounding a charged object is said to be under the influence of:
   - A. an electrostatic field
   - B. an electrostatic discharge
   - C. a dielectric current
   - D. a dielectric discharge

10. An electric force field is represented by arrows pointing away from a positive and toward a negative charge. These arrows represent:
    - A. only the difference between the fields surrounding either charge
    - B. the actual direction of the movement of the field
    - C. the direction a free electron would move when placed in the field
    - D. the constant movement of charges within the field

11. A unit used to measure the amount of an electrostatic charge is:
    - A. the ion
    - B. the atom
    - C. the coulomb
    - D. the volt

Basic Electricity
Test #4
Electric Current

Name: ______________

1. Electric current in a conductor is best described as:
   - A. a general drift of atoms from positive to negative
   - B. a general drift of free protons from positive to negative
   - C. a general drift of free electrons from positive to negative
   - D. a general drift of free electrons from negative to positive

2. When an electric circuit is compared to a pipe system, filled with water, electric current should be compared to:
   - A. the pressure
   - B. the flow of water
   - C. the amount of water enclosed in the total system
   - D. the resistance offered by the pipes

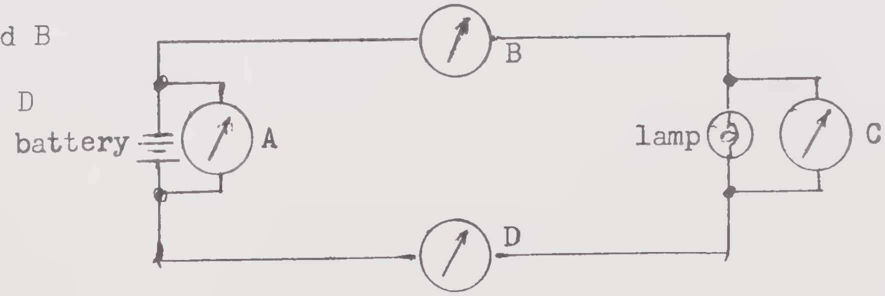
3. When a textbook uses the direction of current flow that is the same as the direction of electron flow, this direction will be:
   - A. from positive to negative
   - B. from negative to positive
   - C. clockwise in a circuit
   - D. counterclockwise in a circuit

4. The following conditions must exist before an electric current can flow. There must be:
   - A. a complete conductive path and an electromotive force
   - B. an electromotive force and an open switch
   - C. a conductive path and a closed switch
   - D. a resistor and an open switch

5. The unit for measurement of electric current is:
   - A. the volt
   - B. the ampere
   - C. the ohm
   - D. the coulomb

6. When three coulombs flow past a given point in one second, the current will be:
   - A. 1/3 amp
   - B. .3 amp
   - C. 1 amp
   - D. 3 amp

7. Which of the following meters is connected correctly to measure the current in the circuit:
   - A. meter A
   - B. meter A and B
   - C. meter C
   - D. meter B or D



8. The current in a circuit is measured to be 10 amps as it leaves the battery. The current in the other parts of the circuit:
   - A. will be zero
   - B. will be the same anywhere in the circuit
   - C. will become gradually lower toward the end of the circuit
   - D. must be measured independently from the first meter

9. A certain number of electrons enter a circuit on the negative end, on the positive end:
   - A. the same number of electrons will leave the circuit
   - B. the same electrons that entered will leave the circuit
   - C. fewer electrons will leave the circuit
   - D. no electrons will be left since they have been used up in the circuit

Basic Electricity
Test #5
Electromotive Force

Name: ____________________

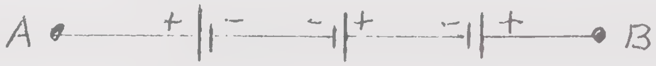
1. When an electric circuit is compared to a pipe system, the emf should be compared to:
   - A. the rate of water flow
   - B. the pressure
   - C. the total amount of water in the system
   - D. the speed of the water flow

2. The unit for emf is
   - A. the volt
   - B. the ampere
   - C. the ohm
   - D. psi

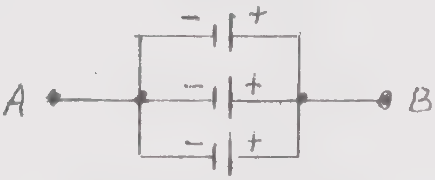
3. The symbols for emf is _____ and for current is _____:
   - A. E and I
   - B. I and E
   - C. G and
   - D. E and

4. When the emf in a given circuit is increased three times, and resistance is unchanged, the current will be:
   - A. 1/3 the original
   - B. unchanged
   - C. 3 times the original
   - D. 9 times the original

5. Three 1.5 volt dry cells are connected in series as shown. The total emf between A and B will be: (Check the diagram carefully!)
   - A. .5 volts
   - B. 1.5 volts
   - C. 3.0 volts
   - D. 4.5 volts



6. Three 1.5-volt dry cells are connected in parallel as shown. The total emf between A and B is:
   - A. .5 volts
   - B. 1.5 volts
   - C. 3.0 volts
   - D. 4.5 volts



7. Another term that could be used in place of emf is:
   - A. all of B, C, and D
   - B. voltage
   - C. potential
   - D. potential difference

8. A given dc circuit has a current of 30 amps when the applied voltage is 120 volts. When the voltage is reduced to 80 volts, the current will be
   A. 0 amps
   B. 20 amps
   C. 30 amps
   D. 40 amps

9. The relationship between emf and current is:
   A. inversely proportional
   B. indirectly proportional
   C. emf is proportional to the square of the current
   D. directly proportional

10. An emf can be present:
   A. only in a circuit that is completely continuous
   B. only in a circuit that has a current flow
   C. only when a voltmeter is connected
   D. without the conditions given in a, b, and c

Basic Electricity
Test #6
Resistance

Name: ____________________

1. The symbol for resistance is:
   A. E
   B. I
   C. R
   D. G

2. The unit for resistance is:
   A. volt
   B. ampere
   C. ohm
   D. mho

3. The symbol for ohm is:
   A. Ω
   B. v
   C. R
   D. o

4. The resistance of insulators is:
   A. very high
   B. low
   C. zero
   D. changing with current flow

5. The resistance of good conductors such as copper is:
   A. very high
   B. very low
   C. zero
   D. changing with applied emf

6. When the resistance in a circuit is increased five times the current will be:
   A. increased five times
   B. decreased to one fifth
   C. unchanged
   D. decrease to zero

7. In an electric circuit resistance and current are:
   A. directly proportional
   B. inversely proportional
   C. not proportional
   D. proportional to the square of each other

8. The symbol for conductance is:
   A. Ω
   B. R
   C. I
   D. G

9. The unit for conductance is:
   A. ohm
   B. mho
   C. conductance
   D. ampere

10. When the conductance in a circuit is 1/10 mho its resistance will be:
   A. 1/10 ohm
   B. 1 ohm
   C. 10 ohms
   D. 100 ohms

Basic Electricity
Test #7
Ohm's Law

Name: ____________________

1. Which of the following statements is correct for the relationship among current, emf, and resistance?
   A. Both C and D are correct
   B. Emf is directly proportional to current and inversely proportional to resistance.
   C. Current is directly proportional to emf and inversely proportional to resistance
   D. Emf is directly proportional to current and resistance.

2. Which of the following procedures can be used to calculate the resistance of a load?
   A. Both B and C can be used.
   B. Divide the current through the load by the voltage across the load.
   C. Multiply the current through the load by the voltage across the load.
   D. Divide the voltage across the load by the current through the load.

3. Which of the following choices shows all three forms of Ohm's Law correctly?
   A. $E = \frac{I}{R}$; $I = \frac{E}{R}$; $R = \frac{I}{E}$

   B. $E = IR$; $I = ER$; $R = \frac{E}{I}$

   C. $E = \frac{I}{R}$; $I = \frac{E}{R}$; $R = EI$

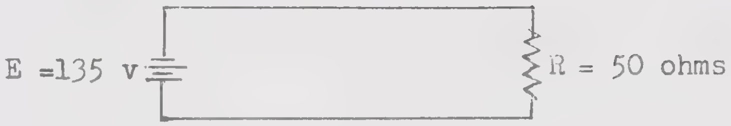
   D. $E = IR$; $I = \frac{E}{R}$; $R = \frac{E}{I}$

4. When a current of 4 amps flows through a resistance of 10 ohms, the value of the applied voltage must be:
   A. 40 volts
   B. 25 volts
   C. 14 volts
   D. 2.5 volts

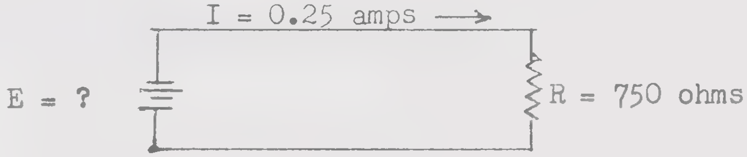
5. When a potential of 10 volts is applied across a resistance of 5 ohms, the current in the circuit is equal to:
   A. 15 amps
   B. 5 amps
   C. 2 amps
   D. 0.5 amps

6. A lamp is connected to 110 volts and draws a current of 0.9 amps. What is the resistance of the lamp?
   A. 122.2 ohms
   B. 12.2 ohms
   C. 0.08 ohms
   D. 0.008 ohms

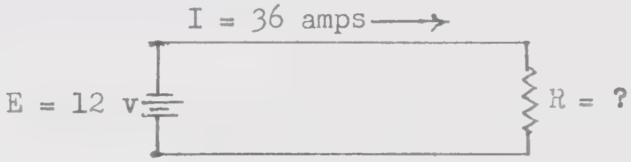
7. The current in the circuit below is:
   A. 7,250 amps
   B. 7.25 amps
   C. 2.5 amps
   D. 0.4 amps



8. The voltage in the circuit below is:
   A. 187.5 volts
   B. 375 volts
   C. 750 volts
   D. 3000 volts



9. The resistance in the circuit below must be:
   A. .33 ohms
   B. 3.0 ohms
   C. 36 ohms
   D. 432 ohms



10. A current of 8 amps flows through a resistor of 20 ohms. It is required to keep the current at the same value when the applied voltage is doubled. In order to do that, the new resistance value must be:
    A. 10 ohms
    B. 20 ohms
    C. 40 ohms
    D. 80 ohms

Basic Electricity
Test #8
Large and Small Values

Name: ____________________

1. One megohm (M) is equivalent to:
   A. 1/1000 ohm
   B. 1/1,000,000 ohm
   C. 1,000 ohm
   D. 1,000,000 ohm

2. One milliamp is equal to:
   A. 1/1000 amp
   B. 1/1,000,000 amp
   C. 1000 amp
   D. 1,000,000 amp

3. One hundred millivolt is the same as:
   A. .00001 volt
   B. .001 volt
   C. .01 volt
   D. .1 volt

4. One thousand microamp is the equivalent of:
   A. 1 amp
   B. 1 milliamp
   C. .000001 amp
   D. .0000001 amp

5. 50 kilo-ohm (kΩ) is the same as:
   A. .05 ohms
   B. 50 ohms
   C. 50,000 ohms
   D. 50,000,000 ohms

6. 35 microamp is equal to:
   A. 3.5 x 10^{-3} amp
   B. 3.5 x 10^{-4} amp
   C. 3.5 x 10^{-5} amp
   D. 3.5 x 10^{-6} amp

7. Which of the following values should not be used directly (without conversion) in an Ohm's law formula?
   A. volts, amperes, and ohms
   B. milliamps, microamps, kilo-ohms
   C. 10^{-3} amps, 10^{-6} amps, 10^{3} ohms, etc.
   D. .001 amps, .000001 amps, 1000 ohms, etc.

8. .00001 is equal to:
   A. 10^{6}
   B. 10^{5}
   C. 10^{-4}
   D. 10^{-5}

9. 2.6×10^5 is equal to:
   A. 26,000
   B. 260, 000
   C. .000026
   D. .0000026

10. 10^0 is equal to:
   A. 1
   B. 0
   C. ∞ (infinity)
   D. an undefined value

11. A value such as 525×10^3 is more commonly expressed as:
   A. 5.25×10^1
   B. 5.25×10^3
   C. 5.25×10^5
   D. 5.25×10^{-1}

12. A resistor of 50 kilo-ohms is connected to 100 volts. The current in the resistor is:
   A. 2×10^{-3} amps
   B. 2×10^{-1} amps
   C. 2×10^0 amps
   D. 2×10^1 amps

13. A current of 50 microamps is measured in a resistor of 100 kilo-ohms. The voltage applied to that resistor is:
   A. 500 volts
   B. 50 volts
   C. 5 volts
   D. .5 volts

Basic Electricity
Test #9
Series Circuits

Name: ____________________

1. If a circuit is constructed so as to allow the electrons to follow only one possible path, the circuit is called a/an:
   A. series-parallel circuit
   B. incomplete circuit
   C. series circuit
   D. parallel circuit

2. In a series circuit of three resistors, the amount of current flowing in one resistor:
   A. depends upon the resistance of that resistor
   B. depends upon the position of that resistor
   C. is the same as the current flowing through the others
   D. is different from the current flowing through the other resistors unless all resistors have the same resistance.

3. The voltage drop in any resistor is equal to the:
   A. current times the resistance
   B. resistance times the emf
   C. emf divided by current
   D. emf divided by the resistance

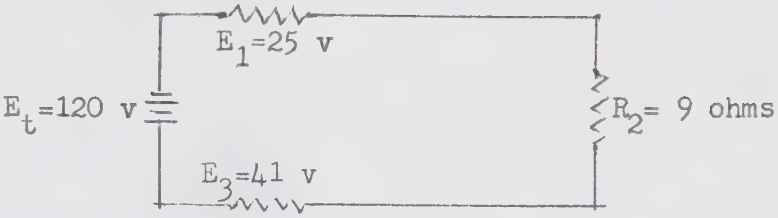
4. Kirchhoff's voltage law can be used to find
   A. the total emf in a series circuit when the individual voltage drops are known
   B. the total current in a series circuit when the individual currents are known
   C. the total emf in a parallel circuit when the individual voltage drops are known
   D. the emf across any one resistor when the resistance and the current of that resistor are known.

5. The total resistance of a series circuit is equal to the:
   A. equivalent resistance squared
   B. product of the individual resistances
   C. sum of the individual resistances
   D. reciprocal of the sum of the individual resistances

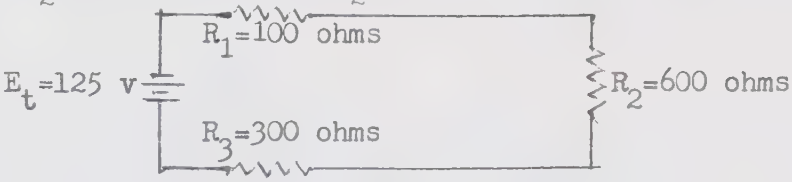
6. In a series circuit with 3 resistors of 3, 4, and 5 ohms, the total resistance is:
   A. 2.4 ohms
   B. 6.2 ohms
   C. .02 ohms
   D. 12 ohms

7. With a 4 ohm and a 2 ohm resistance connected in series across a 12 volt battery, the current flow is:
   A. 6 amperes in the smaller resistor
   B. 3 amperes in the larger resistor
   C. 9 amperes through each resistor
   D. 2 amperes through each resistor

8. The current in the circuit below is:
   A. 6 amps
   B. 10 amps
   C. 13.3 amps
   D. 16 amps



9. The voltage drop V_2 in the resistor R_2 is:
   A. 25v
   B. 75v
   C. 100v
   D. 125v



10. Three resistors of 50 ohms, 60 ohms, and 110 ohms are connected in series across 440 volts. The voltage across the 60-ohm resistor is:
    A. 30 volts
    B. 60 volts
    C. 120 volts
    D. 220 volts

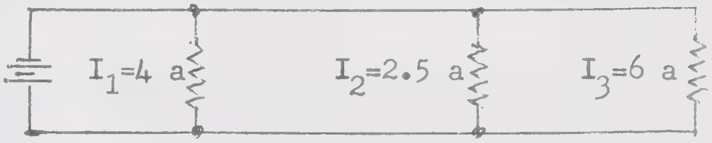
Basic Electricity
Test #10
Parallel Circuits

Name: ____________________

1. For all branches of a parallel circuit
   A. all voltages are always equal
   B. all currents are always equal
   C. all resistances are always equal
   D. the individual voltages are inversely proportional to the resistances

2. In a parallel circuit, the current
   A. is greatest in the highest resistance branch
   B. in each branch is added together to determine the total current
   C. is the same at all points, or through all components
   D. is inversely proportional to the source voltage

3. What is the total current in the circuit below?
   A. .5 a
   B. 1.22 a
   C. 6 a
   D. 12.5 a



4. In a parallel circuit containing a 4 ohm, 5 ohm, and 6 ohm resistor the current flow is
   A. lowest through the 4 ohm resistor
   B. highest through the 4 ohm resistor
   C. highest through the 6 ohm resistor
   D. equal through all three resistors

5. In a group of resistances connected in parallel as part of a circuit:
   A. the greatest resistance has the greatest current
   B. the greatest resistance has the greatest potential across it
   C. the least resistance has the least current
   D. the total resistance is less than the smallest resistance

6. Which two formulas are correct for finding the total resistance of two resistors in parallel?
   A. $R_t = R_1 + R_2$; $R_t = \frac{R_1 \times R_2}{R_1 + R_2}$

   B. $R_t = \frac{R_1 \times R_2}{R_1 + R_2}$; $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2}$

   C. $R_t = \frac{R_1 + R_2}{R_1 \times R_2}$; ; $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2}$

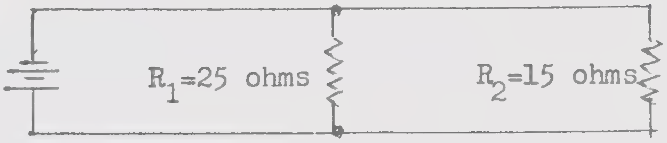
   D. $R_t = \frac{R_1 + R_2}{R_1 \times R_2}$; $R_t = \frac{1}{R_1} + \frac{1}{R_2}$

7. A 36 ohm and an 18 ohm resistor are connected in parallel. Their combined resistance is:
A. 12 ohms
B. 18 ohms
C. 36 ohms
D. 54 ohms

8. The total resistance of 3 resistors of 2, 4, and 8 ohms resistance connected in parallel is:
A. 1.14 ohms
B. 1.98 ohms
C. 6.2 ohms
D. 13.4 ohms

9. Six 300-ohm resistors are connected in parallel. The total resistance of this connection is:
A. .02 ohms
B. 50 ohms
C. 300 ohms
D. 1800 ohms

10. What is the total resistance of the circuit below?
A. .1625 ohms
B. 9.375 ohms
C. 12.5 ohms
D. 40 ohms



Basic Electricity
Test #11
Wire Sizes, Resistance, Temperature-coefficient

Name: ____________________

1. Of the following, the best conductor is:
    A. aluminum
    B. copper
    C. gold
    D. silver

2. A #6 conductor is:
    A. smaller than a #14 conductor
    B. larger than a #14 conductor
    C. double the area of a #3 conductor
    D. half the area of a #9 conductor

3. A number 10 wire has a cross-section area of 10,000 CM. A number 16 conductor will have a cross-section area of:
    A. 10,000 CM
    B. 5,000 CM
    C. 2,500 CM
    D. 1,250 CM

4. A "mil" when used for electrical conductors, means:
    A. one-thousandth of an inch
    B. short for a mile
    C. the diameter of a conductor
    D. unit of measure

5. In a length of wire, the resistance is:
    A. proportional to the length and unaffected by the cross-section
    B. inversely proportional to the length and cross-section area
    C. directly proportional to length and cross-section area
    D. directly proportional to the length and inversely proportional to the cross-section area

6. A wire has the diameter of .05 inch. The circular mil area of this wire is:
    A. 250,000 CM
    B. 2,500 CM
    C. .25 CM
    D. .0025 CM

7. A copper wire of 5,000 CM area is 80 feet long. Its resistance is (K for copper is 10.4):
    A. 41.6 ohms
    B. 1.66 ohms
    C. .416 ohms
    D. .166 ohms

8. A copper conductor of 4,160 CM is 200 ft. long. The resistance of the wire is:
   A. 0.35 ohms
   B. 0.50 ohms
   C. 0.95 ohms
   D. 3.50 ohms

9. A heater coil with 20 ohms resistance must be wound from a resistance wire that has 1,300 CM cross-section area and a k-factor of 520. What length is required?
   A. 2 ft.
   B. 5 ft.
   C. 20 ft.
   D. 50 ft.

10. The field coil in an electric motor has 120 ohms resistance at 20° C. After the motor operated for some time, the temperature increased to 50° C. The resistance of the coil will now be (temperature coefficient for copper is .004):
    A. 14.4 ohms
    B. 114.2 ohms
    C. 121.4 ohms
    D. 134.4 ohms

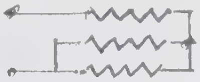
11. The resistance of a copper coil in a transformer is measured at room temperature (20° centigrade) and found to be 10 ohms. After the transformer has been operating for several hours, it is removed from the circuit and the same winding is measured again. The resistance is now 11.6 ohms. These measurements enable us to calculate the temperature that the winding has after the transformer was operating for several hours. (Temperature coefficient for copper .004).
    A. 40° centigrade
    B. 60° centigrade
    C. 66.7° centigrade
    D. 290° centigrade

Basic Electricity
Test #12
Series - Parallel Circuits

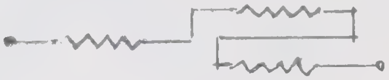
Name: ____________________

1. Which one of the circuits below is a series-parallel circuit?

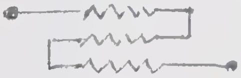
A.



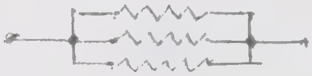
C.



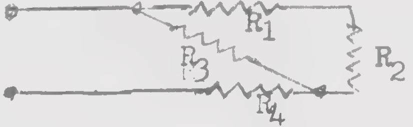
B.



D.

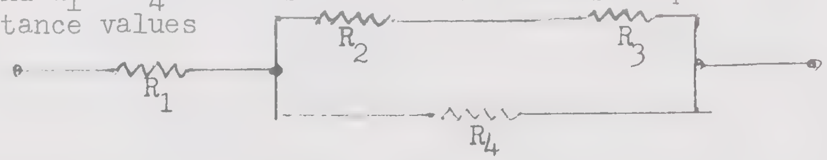


2. In a circuit below the connection of resistors is the following
   A. All resistors are in parallel
   B. Series connection R_1, R_2 is in parallel with R_3 and this connection is in series with R_4
   C. R_1, R_2, R_3 are in parallel and this parallel connection is in series with R_4
   D. The series strings R_1, R_2 and R_3, R_4 are in parallel with each other

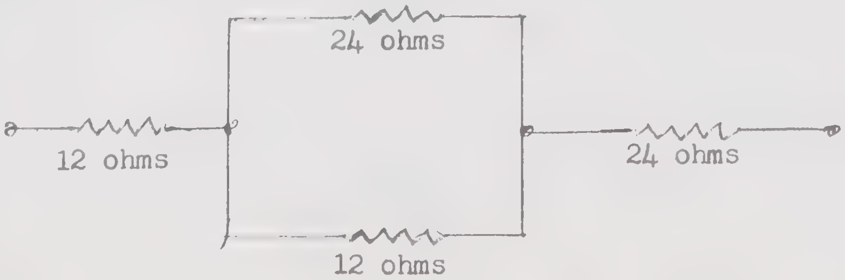


3. Three resistors of 300 ohms each are connected in parallel. This parallel connection is in series with a 200-ohm resistor. The total resistance is
   A. 100 ohms
   B. 120 ohms
   C. 300 ohms
   D. 1100 ohms

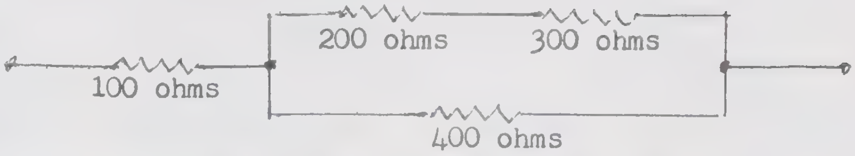
4. In order to find the total resistance for the circuit below, we must
   A. first find $R_2 + R_3$, then find the resistance of the parallel connection of $R_2 + R_3$ with R_4 and add R_1
   B. first find the value of the parallel connection $R_3 + R_4$, add R_2 and then R_1
   C. add $R_2 + R_3$ and $R_1 + R_4$ and calculate these values in parallel
   D. add all resistance values



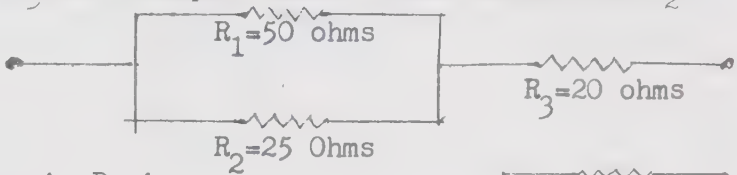
5. The total resistance of the circuit below is
   A. 72
   B. 60
   C. 48
   D. 44



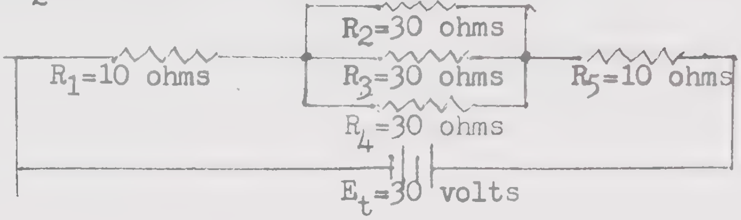
6. The total resistance of the circuit below is
A. 193
B. 323
C. 340
D. 350



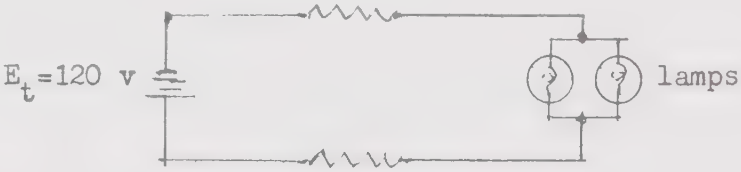
7. The current in R_3 is 15 amps. What is the current in R_2?
A. 15 amp
B. 10 amp
C. 5 amp
D. 0 amp



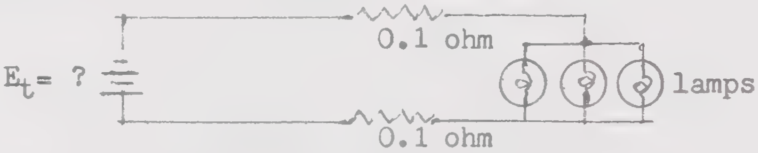
8. The current flow in R_3 is
A. 3.0 amp
B. 1.0 amp
C. .33 amp
D. .272 amp



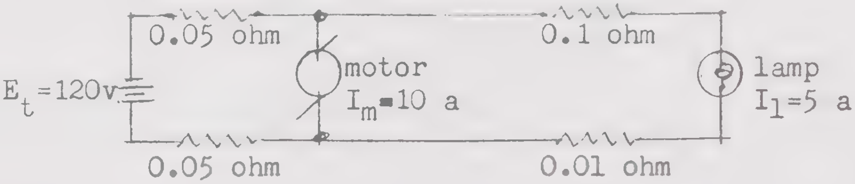
9. The total line voltage drop in the power line below is 2.5 volts. What is the voltage across the lamps
A. 2.5 volts
B. 117.5 volts
C. 120. volts
D. 122.5 volts



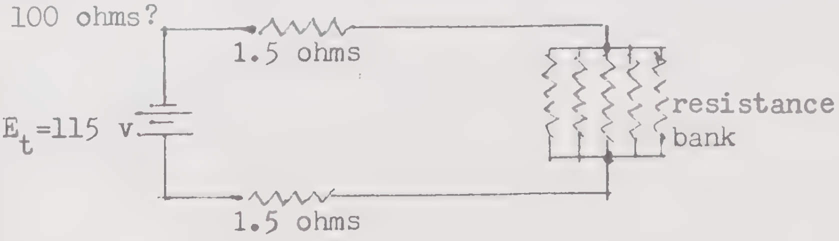
10. Each lamp draws a current of 2 amps. The voltage at the lamp terminals is 117.5 volts. What is the voltage at the source?
A. 118.7 volts
B. 118.1 volts
C. 117.5 volts
D. 116.3 volts



11. In the circuit below, when the motor draws 10 amps and the lamp draws 5 amps, what is the voltage at the lamp terminals?
A. 120 v
B. 118.8 v
C. 118.6 v
D. 117.5 v

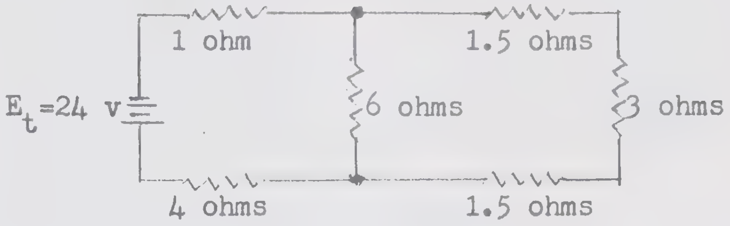


12. What is the voltage across the resistance banks when each resistor in the banks is 100 ohms?
A. 115 v
B. 100 v
C. 23 v
D. 20 v



13. In the circuit below, the voltage drop across the 3-ohm resistor is:

A. 0.96 volts
B. 4.5 volts
C. 24 volts
D. 2.4 volts



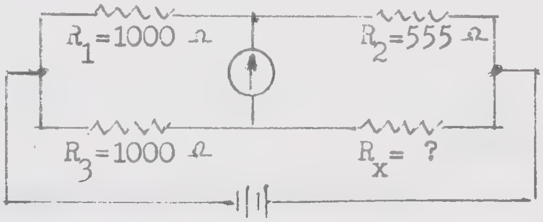
Basic Electricity
Test #13
Wheatstone Bridge and Three-Wire Circuits

1. One application for a Wheatstone Bridge circuit is for accurate
   A. measurements of emf
   B. measurements of current
   C. measurements of resistance
   D. measurement of stresses in bridge installations

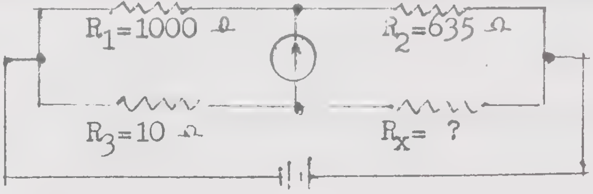
2. The measurement in the Wheatstone Bridge is done by accurate
   A. ratio-comparison between three known and one unknown resistor
   B. measurement of emf in the unknown resistor
   C. measurement of current in the unknown resistor
   D. measurement of the current flowing in the galvanometer

3. A wheatstone Bridge is balanced when
   A. both B and C are true
   B. the ratio $\frac{R_1}{R_3} = \frac{R_2}{R_4}$ is true
   C. there is no current flowing in the galvanometer
   D. the unknown resistor is zero ohms

4. When the bridge is balanced the value of the unknown resistor R_x must be
   A. 555 ohms
   B. 445 ohms
   C. 1000 ohms
   D. either 1000 ohms or 445 ohms

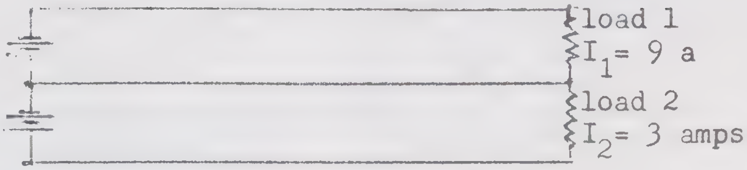


5. For the bridge to be balanced, the value of the unknown resistance R_x must be
   A. 0.635 ohms
   B. 6.35 ohms
   C. 635 ohms
   D. 63500 ohms

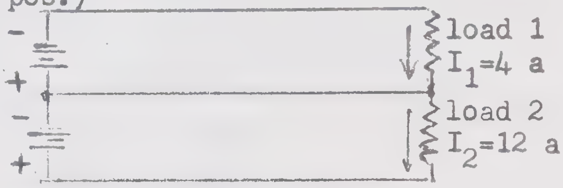


6. Which of the following statements are true as advantages of a 115/230 v three-wire supply system over the ordinary 115 v two-wire system? (i) It can deliver both 115 and 230 volts. (ii) There is usually a lower voltage drop in the supply lines. (iii) It requires less copper (less cross-section area) for the same amount of load. (iv) It requires less insulation for each individual wire.
   A. all of (i), (ii), (iii), and (iv) are true
   B. only (i), (ii), (iii) are true
   C. only (i), and (iv) are true
   D. only (i) and (iii) are true

7. In the three-wire system below, the current in the neutral is
   A. 12 amps
   B. 9 amps
   C. 6 amps
   D. 3 amps

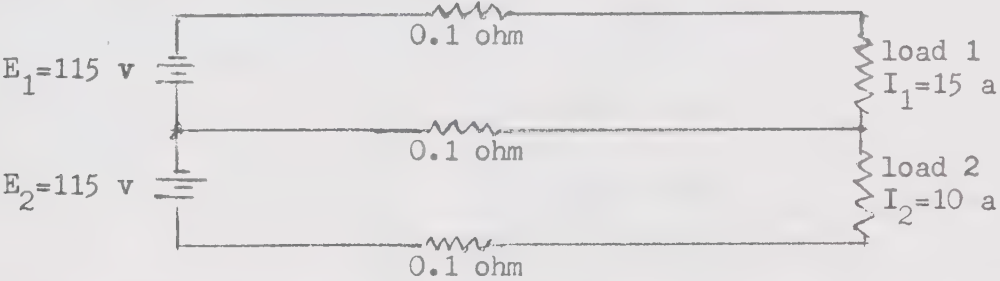


8. In the tree-wire circuit below, the current flow in the neutral (consider current flow from neg. to pos.)
   A. will be from left to right
   B. will be from right to left
   C. will be zero
   D. cannot be determined from the given information

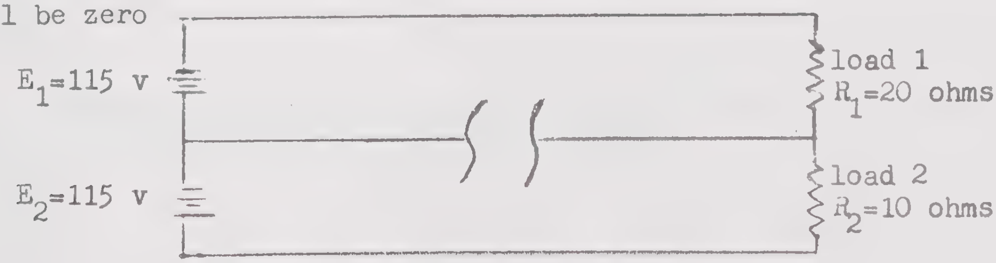


9. One wire in a standard 115/230 v three-wire circuit is normally grounded. The grounded wire is normally
   A. the negative outside wire
   B. the positive outside wire
   C. either one of the outside wires
   D. the neutral wire

10. In the three-wire circuit below, the voltages at the loads will be
   A. load 1: 113.0 v, load 2: 113.5 v
   B. load 1: 113.0 v, load 2: 114.5 v
   C. load 1: 114.0 v, load 2: 113.5 v
   D. load 1: 114.0 v, load 2: 114.5 v



11. When in the three-wire circuit below, the neutral wire is accidentally opened, the voltage at load 1
   A. will be 115 volts
   B. will be higher than 115 volts
   C. will be lower than 115 volts
   D. will be zero

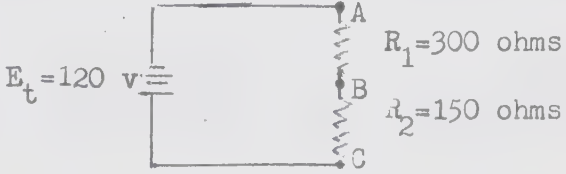


Basic Electricity
Test #14
Voltage Divider Circuits

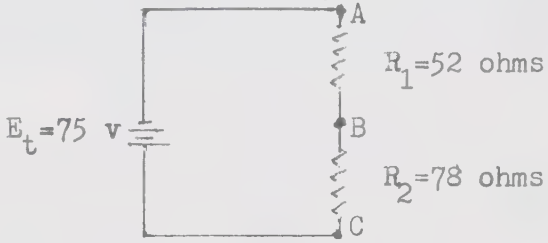
Name: ____________________

1. A voltage divider is basically a connection of
    A. two or more resistors in parallel
    B. two or more resistors in series
    C. one or more resistors in series with a load
    D. one or more resistors in parallel with a load

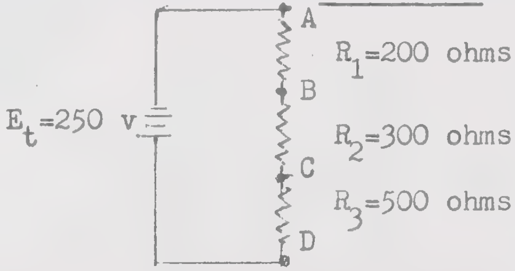
2. The emf between points B and C in the diagram is
    A. 120 v
    B. 80 v
    C. 60 v
    D. 40 v



3. In the voltage divider circuit below, the emf between points B and C is
    A. 12.7 v
    B. 13.5 v
    C. 30 v
    D. 45 v

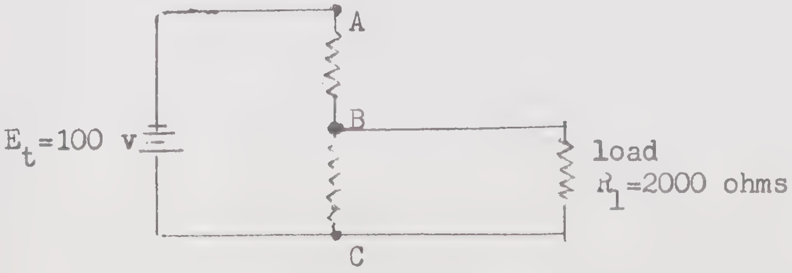


4. In the divider circuit below the voltage between G and C is __________ v, and between G and B it is __________ v.
    A. 125, 250
    B. 125, 200
    C. 0, 250
    D. 100, 160



5. When a load is applied to a voltage divider circuit, the voltage at the points where the load is connected will
    A. drop to zero
    B. decrease
    C. remain exactly the same
    D. increase

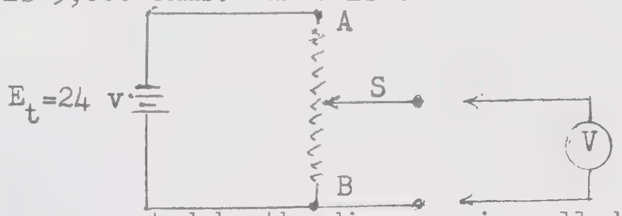
6. The emf between points B and C in the voltage divider circuit below will be __________ volts with the load connected.
    A. 100 v
    B. 50 v
    C. 40 v
    D. 0 v



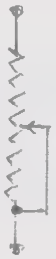
7. In order to make a voltage divider circuit, such as the one shown in the above problem, more stable (so that it varies the voltage less when the load is varied) it would be necessary to
   A. use lower ohms values for the divider resistors R_1 and R_2
   B. use higher ohms values for the divider resistors R_1 and R_2
   C. use lower current in the divider part of the circuit
   D. reverse the resistors R_1 and R_2

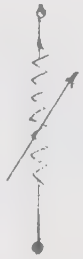
8. When a voltmeter is connected to a voltage divider circuit that uses high resistances (low currents) the reading may be affected by the loading effect of the voltmeter. This loading effect will be smaller when
   A. the voltmeter has a very high internal resistance
   B. the voltmeter has a very low internal resistance
   C. the voltmeter uses relatively large measuring currents
   D. a milliampere meter is used for this measurement

9. In the potentiometer below the slider is set so that there is 1, 250 ohms between point A and point S. The total resistance of the potentiometer is 5,000 ohms. What is the emf between point S and B?
   A. 24 v
   B. 18 v
   C. 6 v
   D. 0 v



10. The instrument represented by the diagrams is called a
   A. both B and C are correct
   B. rheostat
   C. variable resistor
   D. potentiometer





Basic Electricity
Test #15
Electric Power

Name: ____________________

1. Chemical Energy is converted to Electricity by a:
    A. generator
    B. thermocouple
    C. photocell
    D. battery

2. Power is described as the rate at which
    A. work is being done
    B. energy is being used
    C. energy is being expended
    D. all of the above are correct

3. Resistance in the power formula equals:
    A. R= L/P
    B. R= E/I
    C. R= P+I
    D. $R = \frac{E^2}{P}$

4. If the resistance is held constant, what happens to power if the current is doubled?
    A. Power is doubled
    B. Power is multiplied by 4
    C. Power is halved
    D. Power is divided by 4

5. If the resistance is held constant, what is the relationship between power and voltage in a simple circuit?
    A. Resistance must be varied to show a true relationship
    B. Power will vary as the square of the applied voltage
    C. Voltage will vary inversely proportional to power
    D. Power will vary directly with voltage

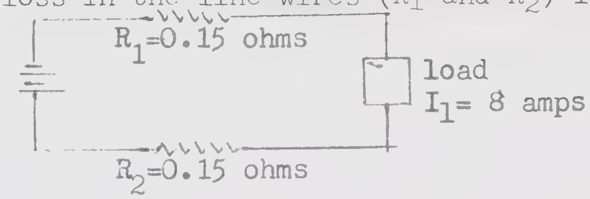
6. What current will be drawn by a soldering iron which has a rating of 600 watts at 110 volts?
    A. 0.182 a.
    B. 5.455 a.
    C. 18.200 a.
    D. 66.000 a.

7. When 0.25 amperes flows through a 1000 ohm resistor the power consumption is:
    A. 6.25 watts
    B. 25 watts
    C. 62.5 watts
    D. 250 watts

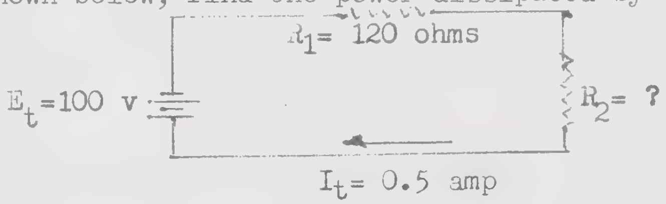
8. The power consumed by a 50 ohm resistor connected to a 150 volt source is:
   A. 30 watts
   B. 75 watts
   C. 300 watts
   D. 450 watts

9. What is the maximum current that should flow through a 500 ohm, 20 watt resistor?
   A. 0.02 amperes
   B. 0.04 amperes
   C. 0.2 amperes
   D. 25 amperes

10. What is the total power loss in the line wires (R_1 and R_2) in the circuit shown?
   A. 1.2 watts
   B. 2.4 watts
   C. 9.6 watts
   D. 19.2 watts



11. In the circuit shown below, find the power dissipated by R_2.
   A. 10 watts
   B. 20 watts
   C. 25 watts
   D. 55 watts



Basic Electricity
Test #16
Electrical Energy

Name: ____________________

1. Mechanical energy is converted to electrical energy by:
   A. a transformer
   B. a generator
   C. a motor
   D. a relay

2. When current flows in the line wires between an electric generator and a load, some electric energy will be "lost" due to the resistance of the line wires. This energy is not really "lost" but merely converted into:
   A. voltage drop
   B. heat
   C. magnetism
   D. mechanical energy

3. A generator in a power plant delivers 950 amps at 13,000 volts. The power produced by the generator is:
   A. 12.4 mega watt
   B. 8.75 mega watt
   C. 875 kilo watt
   D. 1340 watt

4. A 100-watt lamp is left on for 24 hours. The amount of electrical energy used in that time is:
   A. 4.16 watt-hours
   B. 24 watt-hours
   C. 2.4 kilowatt-hours
   D. 2400 kilowatt-hours

5. A 1.5 kw electric kettle is left on for 40 minutes. The power company charges 3 cents per kilowatt-hour. What is the cost of the electrical energy used in that time?
   A. 1.5 ¢
   B. 3 ¢
   C. 4.5 ¢
   D. $1.80

6. A 1200-watt toaster is used for 5 minutes every morning for one month (30 days). The cost for one kilowatt-hour of electrical energy is 2.5 cents. What will be the cost for operating this toaster for one month?
   A. 7.5¢
   B. 18¢
   C. 62.5¢
   D. $3.75

7. The joule is a metric unit of energy. It is equal to:
   A. one kilowatt
   B. one kilowatt-hour
   C. one watt-second
   D. one milliwatt

8. Electrical energy can be converted to almost any other form of energy, e.g. light, mechanical energy, heat, radiation, etc. Among the more commonly used electrical appliances the ones that use the most electric power are usually the ones that convert electrical energy into:
   A. heat
   B. light
   C. electromagnetic waves
   D. magnetism

9. A 220- volt hotplate is used to heat one gallon of water to the boiling point. The hot plate draws 5 amperes current (at 220 v) and it takes $\frac{1}{4}$ hour to heat the water to the boiling point. On another occasion the same hot plate is used on a 110-volt supply. How long will it take now to heat the one gallon of water? (Assume that the heat losses due to radiation and evaporation do not change, i.e. the same amount of energy is necessary to heat the water. Also assume that the resistance of the hotplate has not changed.)
   A. 1/4 hr.
   B. 1/2 hr.
   C. 3/4 hr.
   D. 1 hr.

10. Which of the following sets of measurements could be used to determine the amount of electrical energy used?
   A. emf, current, and resistance
   B. emf, current, and time
   C. resistance, current, and power
   D. emf, current, and power

Basic Electricity
Test #17
Batteries

Name: ____________________

1. In a sulfuric acid solution, (H_2SO_4 + H_2O), the SO_4 will chemically dissociate. i.e., it will break up to form ions. In this process the hydrogen will lose electrons while the SO_4 part will gain electrons. The ions formed are:
   A. negative hydrogen ions and neutral SO_4 ions.
   B. positive hydrogen ions and neutral SO_4 ions.
   C. negative hydrogen ions and positive SO_4 ions.
   D. positive hydrogen ions and negative SO_4 ions.

2. Electrolysis is the process where:
   A. an emf is generated by a chemical reaction.
   B. a current is created by a chemical reaction.
   C. a chemical compound is permanently split by an electric current.
   D. a chemical compound is dissociated into positive and negative ions.

3. In electroplating the positive silver ions will be deposited on the electrode that is connected to the:
   A. positive side of the power supply.
   B. negative side of the power supply.
   C. electrode made of made of material with a higher chemical affinity to silver.
   D. carbon electrode.

4. In a battery, chemical action will cause the positive plate to:
   A. gain protons.
   B. lose protons.
   C. gain electrons.
   D. lose electrons.

5. Corrosion of machinery and installations is usually worse when moisture is present and when:
   A. the temperature is low.
   B. there are two surfaces of dissimilar metals in contact.
   C. oil is mixed with the moisture.
   D. there are two surfaces of the same metal in contact.

6. An electrochemical cell in which the reactions are not reversible (that cannot be recharged) is properly called:
   A. a dry cell.
   B. a secondary cell.
   C. a wet cell.
   D. a primary cell.

7. The purpose of manganese dioxide in a dry cell is:
   A. to absorb the electrolyte.
   B. to prevent corrosion.
   C. to reduce polarization.
   D. both B & C are true.

8. What is the most important advantage of a typical lead-acid storage cell when compared to an ordinary dry cell?
   A. It produces a higher voltage.
   B. It can deliver a higher current.
   C. It can store more ampere-hours.
   D. It can be recharged.

9. A storage battery that is superior in mechanical strength, low water consumption low internal resistance, and low general maintenance is:
   A. the nickel-cadmium cell.
   B. the Edison cell.
   C. the lead-acid cell.
   D. the Daniell cell.

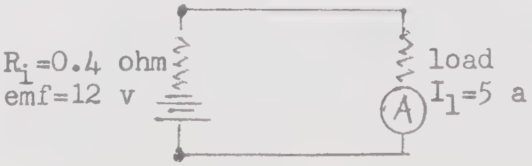
10. The ampere-hour rating of a storage battery is based on:
    A. the discharge current times hours, based on a 20-hour discharge.
    B. the amperes and the hours required to charge the battery to full capacity.
    C. the amperes times the hours that the battery can deliver.
    D. the discharge current that the battery can deliver for one hour.

11. A storage battery of a certain ampere-hour rating delivers:
    A. less energy when the discharge current is high.
    B. more energy when the discharge current is high.
    C. approximately the same amount of energy on a high or low discharge current.
    D. less than the rated energy when discharged over a period of 20 hours.

12. A car battery is rated at 60 ampere-hours. When this battery is used at zero degree Farenheit the actual capacity will be approximately:
    A. 96 ampere hours.
    B. 60 ampere hours.
    C. 24 ampere hours.
    D. 0 ampere hours.

13. To test the exact condition of a battery it is desirable to measure the terminal voltage with a normal load current flowing because:
    A. the terminal emf will increase with load due to polarization.
    B. the terminal voltage will be zero unless a load current flows.
    C. a load current will start the chemical reaction and this will increase emf.
    D. there will be an internal voltage drop due to the resistance and the load current.

14. The terminal voltage of the battery in the diagram below is:
    A. 2.0 volts.
    B. 3.0 volts.
    C. 6.0 volts.
    D. 10.0 volts.



Basic Electricity
Test #18
Magnetism

Name: ____________________

1. How do magnetic material differ from nonmagnetic materials?
   A. In magnetic materials all orbitals that contain only one electron are lined up in the same direction.
   B. Magnetic materials form domains.
   C. In magnetic materials all electrons spin in the same direction.
   D. The nuclei of atoms in magnetic materials have magnetic north and south poles.

2. The theory of magnetism states that a magnetic field is created by moving electric charges. In a permanent magnet the movement of electric charges is the
   A. movement of domains.
   B. spinning of electrons.
   C. the vibration of molecules.
   D. the rotation of atoms.

3. Select the choice that represents only the most commonly used magnetic materials.
   A. manganese, copper, aluminum.
   B. sodium, iron, alnico.
   C. iron, cadmium, zirconium.
   D. iron, nickel, cobalt.

4. If a compass is placed at the center of a bar magnet, the compass needle
   A. points to the geographic south pole
   B. points to the geographic north pole
   C. alines itself parallel to the bar
   D. alines itself perpendicular to the bar

5. The direction of flow of the lines of force around a bar magnet is:
   A. out of the South pole into the North pole.
   B. out of the North pole into the South pole.
   C. equally out of either pole into the other.
   D. from one magnet to another magnet only.

6. Which of the materials listed is the most suitable for a permanent magnet?
   A. soft iron
   B. laminated iron
   C. hardened steel
   D. soft iron filings set in an epoxy resin

7. Magnetic saturation of a material is the condition when
   A. almost all domains are lined up in the same direction.
   B. almost all atoms are formed into magnetic domains.
   C. almost all domains are permanently held in the same direction.
   D. magnetic domains are so closely packed that there is no unmagnetic space between them.

8. The attraction between a north and a south pole can be explained by the fact that magnetic lines have the tendency
   A. to repel each other when in parallel and in the same direction.
   B. to form complete loops.
   C. to prefer to travel through magnetic materials.
   D. to try to shorten their length.

9. Which one of the statements about magnetic lines of force is incorrect?
   A. Lines of force always begin at a north pole and end at a south pole.
   B. Lines of force travel from south to north inside a magnet.
   C. Lines of force prefer magnetic materials.
   D. Lines of force generally try to take the shortest path.

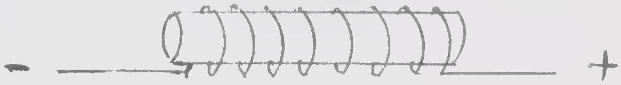
10. In order to protect a delicate instrument from a strong magnetic field it should be shielded with
   A. a nonmagnetic material
   B. a magnetic material
   C. a diamagnetic material
   D. a paramagnetic material

Basic Electricity
Test #19
Electromagnetism

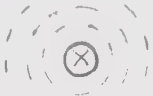
Name: ____________________

1. A current of 0.2 amps is flowing in a coil of 2000 turns. The mmf created by this coil is
   A. 100 AT
   B. 400 AT
   C. 2000 AT
   D. 10,000 AT

2. In the current carrying coil shown the magnetic field will arrange itself so that
   A. lines of force have a counterclockwise direction around the coil when viewed from the right.
   B. lines of force have a clockwise direction around the coil when viewed from the right.
   C. a magnetic north pole will form at the left of the coil.
   D. a magnetic south pole will form at the left of the coil.



3. The diagram indicates the cross-section of a conductor and uses the standard method of indicating current flow. If this is electron current, it will set up lines of force that are
   A. counterclockwise around the conductor
   B. clockwise around the conductor.
   C. in parallel with the conductor in the direction of the current flow.
   D. in parallel with the conductor in the direction opposite to current flow.



4. The magnetic field around a current-carrying wire
   A. is parallel to the current flow in the conductor
   B. exists at all points along its length
   C. exists only at the beginning of electron movement
   D. moves in the direction of the current flow

5. The word permeability indicates the
   A. Amount of reluctance of one centimeter-cube of air
   B. Number of turns of an air core
   C. Ability of material to conduct magnetic lines of force
   D. M.M.F. required to produce one gilbert

6. Permeability is the opposite of:
   A. magnetic reluctivity
   B. magnetic attraction
   C. ohmic resistance
   D. magnetomotive force

7. Direct current flows through a coil of wire which has an iron core. When the core is removed and all other factors remain unchanged, the total number of lines of force through the coil will change because
   A. changing the core material affects the m.m.f.
   B. permeance has been increased.
   C. reluctance has been increased.
   D. the permeability of the magnetic circuit has been increased.

8. When the current in an electromagnet is increased, the magnetic field:
   A. is not affected
   B. expands
   C. contracts
   D. disappears

9. If a compass is placed in the vicinity of a conductor carrying dc, the needle will align itself
   A. in the direction of current flow in the conductor
   B. at the right angles to the conductor
   C. in the general direction of the north pole
   D. in the general direction of the south pole

10. If the direction of the current through a conductor is known and is considered to be from negative to positive, the direction of the magnetic field may be found by the:
    A. right-hand rule
    B. left-hand rule
    C. Fleming's rule
    D. Faraday's rule

11. Of the following, the greatest reluctance is offered by:
    A. air
    B. iron
    C. steel
    D. laminated iron

12. The word reluctance means:
    A. the property of a material to conduct lines of force.
    B. the opposition that a magnetic circuit offers against the setting up of lines of force.
    C. the number of lines of force force for a certain area.
    D. the amount of residual magnetism in a magnetic circuit.

13. A coil of wire which produces magnetism when an electrical current is passed through it, is known as a:
    A. rheostat
    B. starter
    C. solenoid
    D. amplifier

Basic Electricity
Test #20
Magnetic Circuits

Name: ____________________

1. Select the choice that show the symbols for flux density, magnetizing force, and permeability in their respective order.
   A. $\mathcal{F}$, Φ, μ
   B. Φ , $\mathcal{F}$, $\mathcal{R}$
   C. H , B, μ
   D. B , H, μ

2. The weber is the unit of flux that is commonly used in the mks system. One weber is equal to
   A. 10^3 lines of force.
   B. 10^6 lines of force.
   C. 10^7 lines of force.
   D. 10^8 lines of force.

3. When the core of an electromagnet is removed, it retains some of its magnetic properties. This is due to the
   A. internal resistance
   B. residual magnetism
   C. magnetic reluctance
   D. dielectric field

4. A magnetic circuit that has a complete loop of magnetic material:
   A. has no practical applications.
   B. has high eddy currents.
   C. has low reluctance.
   D. has low resistance.

5. A coil wound on an iron core which has a certain reluctance .
   This reluctance is a direct measure of:
   A. the total force producing flux.
   B. the ability of the core to oppose eddy currents.
   C. the core's ability to concentrate flux.
   D. the core's opposition to flux.

6. The permeability of a material is:
   A. low for magnetic materials.
   B. high for air.
   C. always constant.
   D. changing with flux density.

7. A flux density of 4,000 lines through 4 sq. cm. is the equivalent of:
   A. 16,000 gauss
   B. 16,000 oersted
   C. 1,000 gilberts
   D. 1,000 gauss

8. A magnetizing curve shows that in a magnetic material such as soft iron the effect of saturation becomes more pronounced at flux densities over 80,000 lines per square inch. In such material a magnetizing force of 20 A.T. per inch will produce a flux density of 80,000 lines per square inch. When the magnetizing force is doubled to 40 A.T. per inch, we can expect a flux density of about
   A. 40,000 lines per square inch.
   B. 80,000 lines per square inch.
   C. 100,000 lines per square inch.
   D. 160,000 lines per square inch.

9. The negative (reverse) magnetizing force that is necessary to neutralize any residual magnetism in a magnetic material is measured as
   A. coercive force.
   B. magnetomotive force.
   C. retentive force.
   D. domain force.

10. Hysteresis losses are due to the:
   A. constant reversal of the magnetic lines of force in the iron core.
   B. leakage between winding
   C. use of direct current in the primary
   D. none of the above are correct

11. Hysteresis losses would be greater in
   A. Air
   B. Soft iron
   C. Hardened Steel
   D. Aluminum

12. On a graph representing the properties of magnetic material the hysteresis loop would become wider when
   A. the flux density increases
   B. the coercive force of the material is greater
   C. the permeability of the material decreases
   D. the magnetomotive force becomes highly negative.

13. The core of a transformer consists of a complete loop of magnetic material. The total length of this loop is 15 inches. One coil on the transformer has 30 turns, and a current of 5 amps flow in the coil. The magnetizing force in the magnetic material is
   A. 10 A.T. per inch
   B. 90 A.T. per inch
   C. 150 A.T. per inch
   D. 2250 A.T. per inch

14. A d.c. generator has a total pole area of 1.5 square meter and the flux density at the pole surface is 0.3 weber per square meter. The total flux developed by the generator poles is
   A. 0.20 weber
   B. 0.45 weber
   C. 4.5 weber
   D. 5.0 weber

Basic Electricity
Test #21
D. C. Measuring Instruments

Name: ____________________

1. The basic D.C. meter movement utilizes:
   - A. one permanent magnet
   - B. two permanent magnets
   - C. two electromagnets
   - D. both a permanent and an electromagnet.

2. A moving coil or D'Arsonval movement measures the value of
   - A. a direct current flowing through it.
   - B. an alternating current flowing through it.
   - C. both ac and dc current flowing through it.
   - D. either ac or dc power connected to it.

3. The essential difference between a voltmeter and an ammeter is that the:
   - A. voltmeter has a high iternal resistance
   - B. ammeter has a high iternal resistance
   - C. voltmeter has a low iternal resistance
   - D. ammeter has no iternal resistance

4. A voltage multiplier is connected:
   - A. in series with the meter movement
   - B. in parallel with the meter movement
   - C. across the line
   - D. across the meter movement

5. If the full-scale-deflection current of a meter movement is 1 ma and the internal resistance of the movement is 100 ohms, what is the maximum voltage that can be measured with this meter using a multiplier of 99,900 ohms?
   - A. 1 volt
   - B. 10 volts
   - C. 100 volts
   - D. 1000 volts

6. A voltmeter with a sensitivity of 4000 ohms-per-volt is switched to the 250-volt range. What is the input (internal) resistance of the meter at this range?
   - A. 16 ohms
   - B. 100 ohms
   - C. 100,000 ohms
   - D. 1,000,000 ohms

7. A voltmeter using a 50μa (micro-amp) meter movement has a sensitivity of
   - A. 1,000 ohms/volt
   - B. 5,000 ohms/volt
   - C. 20,000 ohms/volt
   - D. 50,000 ohms/volt

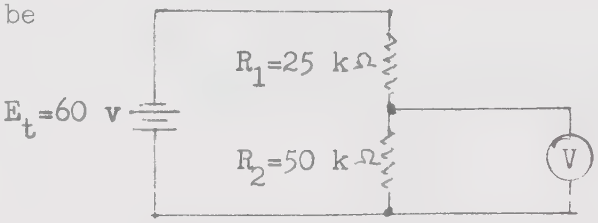
8. A voltmeter that has a sensitivity of 10,000 ohms per volt. From this information we can determine that the meter uses a movement with an fsd current of
   A. 10^{-2} amps
   B. 10^{-3} amps
   C. 10^{-4} amps
   D. 10^{-5} amps

9. We wish to measure voltages up to 300 volts. Our meter specifications are: $I_m = 5$ ma, $R_m = 50$ ohms. We require a multiplier of
   A. 600 kilo-ohms
   B. 599,950 ohms
   C. 60 kilo-ohms
   D. 59,950 ohms

10. Another name for a D'Arsonval movement is
   A. a voltmeter
   B. an ammeter
   C. a moving-coil meter
   D. a moving magnet meter

11. A galvanometer is a meter that
   A. measures only galvanic current
   B. has the zero in the center of the scale
   C. measures voltages without producing any loading effect
   D. does not employ a permanent magnet

12. A voltmeter with a 1000 Ω/v rating is used to measure the emf on the divider circuit below. The meter is set to the 50-volt range. The reading on the meter will be
   A. 60 v
   B. 40 v
   C. 30 v
   D. 0 v



13. The meter in the problem above is switched to the 100-volt range. It remains connected to the same divider circuit. The meter reading is
   A. 60 v
   B. 40 v
   C. 34 v
   D. 30 v

Basic Electricity
Test #22
Ammeters, ohmmeters

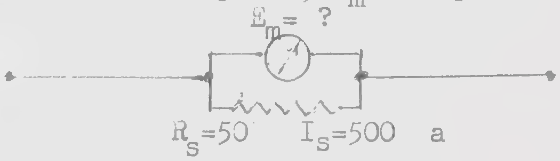
Name: ______________________

1. The essential difference between a voltmeter and an ammeter is that the:
   A. voltmeter has a high iternal resistance
   B. ammeter has a high iternal resistance
   C. voltmeter has a low iternal resistance
   D. ammeter has no iternal resistance.

2. A shunt for a milliammeter will
   A. extend the range and reduce the meter's resistance
   B. extend the range and increase the meter's resistance
   C. decrease the range and the meter's resistance.
   D. decrease the range but increase the meter's resistance.

3. To double the current range of a 50 μa 2,000 ohm meter movement, the shunt resistance should be
   A. 40 ohms
   B. 50 ohms
   C. 2,000 ohms
   D. 18,000 ohms

4. When R_s = 50 ohms and I_s = 500 microamperes, E_m is equal to:
   A. 25 volts
   B. 10 volts
   C. 25 millivolts
   D. 10 millivolts



5. We wish to extend the range of a 100-microampere meter movement to read 1 ma. full scale. Which of the following precision resistors would you use if the internal resistance of the original movement is 91.0 ohms?
   A. 9.1 ohms
   B. 10.1 ohms
   C. 11.0 ohms
   D. 91 ohms

6. In an ammeter with R_m = 250 ohms and I_m = 50 ma, the maximum current that can be measured using a shunt of 0.501 ohm is:
   A. 600 amperes
   B. 250 amperes
   C. 60 amperes
   D. 25 amperes

7. One component of an ohmmeter that is not found in volt-or ammeters is
   A. the multiplier
   B. the range selector
   C. the shunt resistor
   D. the battery

8. An ohmmeter has a total internal resistance of 1500 ohms. What would be the ohms reading at the center of the scale for this ohmmeter?
   A. 750 ohms
   B. 1500 ohms
   C. 3000 ohms
   D. 15000 ohms

9. A V.O.M. is used to measure:
   A. only resistance
   B. only volts
   C. only small currents
   D. any of the above

10. To increase the resistance range of an ohmmeter so that higher resistance values can be measured it would be best to
    A. use a more sensitive meter and more than one dry cell
    B. use a lower internal resistance and a lower rheostate for the zero adjust
    C. use a current shunt in parallel to the meter movement
    D. use a linear scale and a movement that produces linear deflection.

ELECTRICITY 12

MULTIPLE CHOICE TEST Total number of questions: 40

Check this booklet for 7 complete pages

Mark the letter on the answer sheet that corresponds to what you think is the best choice for each question.

NOTE: You will find that for some questions there may be several partly correct choices. You are to select the one choice that you think will best answer the question or complete the statement.

EXAMPLE:

1. What is the most important advantage of a typical lead-acid storage cell when compared to an ordinary dry cell?

   A. It produces a higher voltage.
   B. It can be recharged.
   C. It can deliver a higher current.
   D. It can store more-ampere-hours.

Note, that A,C, and D are partly correct, but B is the most important characteristic of a lead-acid cell.

ANSWER ON THE I.B.M. ANSWER SHEET AS INSTRUCTED - USE H.B. PENCIL

1. The electrical charges in an atom are distributed in the following manner: Protons ____________, neutrons __________, electrons ________.
   A. positive, no charge, negative.
   B. positive, negative, no charge.
   C. no charge, positive, negative.
   D. negative, no charge, positive.

2. The electrons of metal atoms which are located in the highest energy band (outermost shell)
   A. are not very tightly held to the atom.
   B. have the highest electrical charge.
   C. have the lowest electrical charge.
   D. do not participate in the conduction of electric current.

3. In static electrical terms
   A. a negatively charged body has a lack of electrons.
   B. a positively charged body has lost some protons.
   C. like charges attract and unlike charges repel.
   D. none of the above.

4. In an electric circuit electrons are considered to move from
   A. left to right.
   B. right to left.
   C. negative to positive.
   D. positive to negative.

5. Six cells of 1.5 volts each, when connected in parallel will produce an output voltage of
   A. 1.5 volts.
   B. 3 volts.
   C. 9 volts.
   D. 12 volts.

6. The pricipal effect of resistance in a simple circuit is
   A. the creation of electric current.
   B. the increase of current flow.
   C. the limitation of current flow.
   D. the conversion of resistance to conductance.

7. The conductance of a circuit increases
   A. when the resistance increases
   B. when the voltage decreases.
   C. when the resistance decreases.
   D. when the current decreases.

8. In any direct current circuit the current is
   A. directly proprotional to voltage and inversely proportional to the resistance.
   B. directly proportional to the resistance and inversely proportional to the voltage.
   C. indirectly proportional to the resistance and inversely proportional to the conductance.
   D. indirectly proportional to the resistance and inversely proportional to the voltage.

9. A resistor of 50 ohms is connected to 125 volts. What current will it draw?
   A. 6250 amps.
   B. 6 amps
   C. 2.5 amps.
   D. 0.4 amps.

10. A relay with a coil resistance of 250 Ohms requires a direct current of 0.2 amps for its operation. It must be connected to a d.c. source of
   A. 3 volts.
   B. 7.5 volts.
   C. 50 volts.
   D. 1250 volts.

11. The voltage required to cause a current of 50 microamps to flow through a resistance of 150 kilo-ohms is
   A. 3 volts.
   B. 7.5 volts.
   C. 3000 volts.
   D. 7500 volts.

12. Which of the following methods is correct for finding the circular mil (CM) area of a round electrical conductor?
   A. $(\text{diameter in mils})^2 \times 3.14$
   B. $(\text{diameter in mils})^2$
   C. $(\text{diameter in inches})^2 \times 3.14$
   D. $(\text{diameter in millimeters})^2$

13. A copper wire with 0.2 inch diameter has an area of
   A. 200 circular mils.
   B. 400 circular mils.
   C. 20,000 circular mils.
   D. 40,000 circular mils.

14. In a length of wire the resistance is
   A. proportional to the length and unaffected by the cross-section.
   B. inversely proportional to length and to cross-sectional area.
   C. directly proportional to length and to cross-sectional area.
   D. directly proportional to the length and inversely proportional to the cross-sectional area.

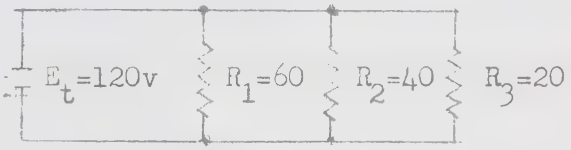
15. During the operation of a transformer the temperature of the copper copper coils in the transformer increased from 20° to 40° C. This increase in temperature will cause
   A. a slight decrease in the resistance of the coils.
   B. no change in the resistance of the coils.
   C. a slight increase in the resistance of the coils.
   D. a doubling of the resistance of the coils.

16. In a series circuit of three resistors, the amount of current flowing through one resistor
  A. depends upon the resistance of that resistor.
  B. depends upon the position of that resistor in the circuit.
  C. is the same as the current flowing through the other resistors.
  D. may be different from the current through the other resistors.

17. Resistances of 100 ohms, 200 ohms, 300 ohms, and 1 megohm are connected in parallel. The total resistance is
  A. more than one megohm.
  B. about one megohm.
  C. about 600 ohms.
  D. less than 100 ohms.

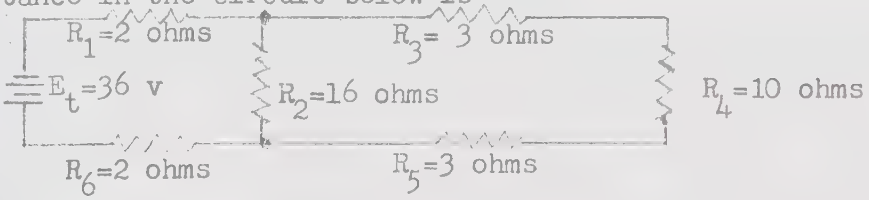
18. Two resistors of 250 ohms and 350 ohms are connected in parallel. The total resistance of this connection is closest to:
  A. 146 ohms.
  B. 187 ohms.
  C. 300 ohms.
  D. 600 ohms.

19. In the circuit below the voltage at the resistors R_1, R_2, and R_3 in their respective order are
  A. E_1=60 v, E_2=40 v, E_3=20 v.
  B. E_1= 2 v, E_2= 3 v, E_3=60 v.
  C. E_1=20 v, E_2=40 v, E_3=60 v.
  D. E_1=120v, E_2=120v, E_3=120v.



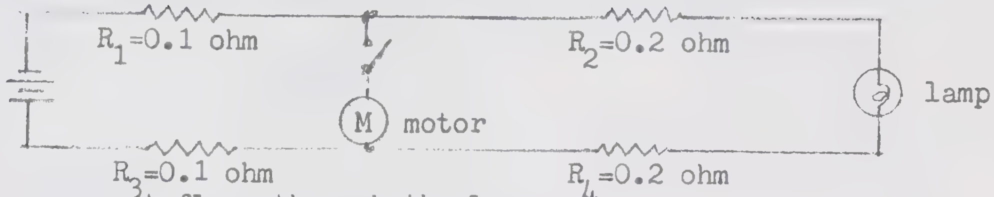
20. Kirchhoff's voltage law in its basic form should be used only in
  A. series circuits.
  B. parallel circuits.
  C. series-parallel circuits.
  D. experimental circuits.

21. The total resistance in the circuit below is
  A. 12 ohms.
  B. 16.5 ohms.
  C. 18.7 ohms.
  D. 22 ohms.



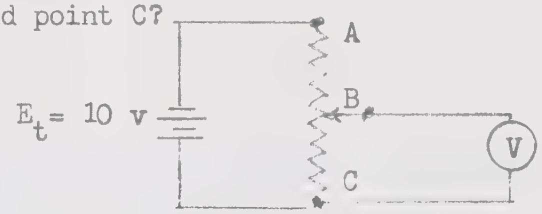
22. The current in resistor R_4 in the diagram in the above question is
  A. 8 amps.
  B. 1.5 amps.
  C. 3 amps.
  D. 6 amps.

23. Which of the statements is true for the diagram below when the motor M is started?



A. more current flows through the lamp.
B. the line resistance R_2 and R_4 increases.
C. the voltage drop across R_1 and R_3 decreases.
D. the voltage drop across R_1 and R_3 increases.

24. A 500-ohm potentiometer is connected to a 10-volt source as shown below. The voltmeter (a VTVM) reads 7 volts. What is the resistance between the slider contact B and point C?
A. 150 ohms.
B. 350 ohms.
C. 493 ohms.
D. 500 ohms.



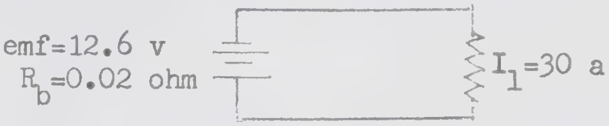
25. A 120-volt electric outlet is protected by a 10-amp fuse. Three appliances rated at 500 watts, 200 watts, and 400 watts are connected in parallel to the line. The fuse will
A. burn out immediately.
B. burn out after a short period of time.
C. not burn out.
D. burn out and restore the circuit automatically.

26. What is the maximum voltage that should be applied to a 500-ohm 5-watt resistor?
A. 10 volts.
B. 50 volts.
C. 100 volts.
D. 2500 volts.

27. An electric heater used 2000 watts when it is connected to 230 volts. When the voltage is reduced to 115 volts, the same heater will use
A. 4000 watts.
B. 2000 watts.
C. 1000 watts.
D. 500 watts.

28. The electrolyte of a lead-acid cell is
A. sal ammonia.
B. manganese dioxide.
C. sulfuric acid.
D. muriatic acid.

29. The total internal resistance of the 12.6-volt battery in the circuit below is 0.02 ohms. What is the terminal (output) voltage of the battery when a load current of 30 amps is drawn from the battery?
    A. 12.6 v.
    B. 12.54 v.
    C. 12.3 v.
    D. 12.0 v.



30. When a magnetic circuit is compared with an electric circuit then
    A. flux could be compared with current.
    B. reluctance could be compared with resistance.
    C. mmf could be compared with emf.
    D. all of the above.

31. In what material is residual magnetism most apparent?
    A. hardened steel.
    B. soft iron.
    C. copper.
    D. wood.

32. The strength of an electromagnet depends on a number of factors. What are the most important ones of these factors?
    A. Current, number of turns, shape, and type of core material.
    B. Voltage, size of wire, lenth and diameter of coil.
    C. Current, number of turns, spacing of windings and layers.
    D. Ratio of diameter to length of the coil and the power used.

33. A wire penetrating this page with the current flow from negative to positive downward into the page has a magnetic field that is
    A. counterclockwise when drawn on this page.
    B. clockwise when drawn on this page.
    C. parallel to the wire going into the page.
    D. parallel to the wire coming up from the page.

34. The permeability of a magnetic material becomes lower when the magnetizing force increases because of the effect of
    A. hysteresis.
    B. eddy currents.
    C. saturation.
    D. coercive force.

35. If an iron core is inserted partly into a coil and a current is applied to the coil, the core will be drawn into the coil in an effort to
    A. increase the reluctance of the magnetic field.
    B. decrease the length of the magnetic circuit.
    C. reduce the permeability of the magnetic circuit.
    D. increase the effect of residual magnetism.

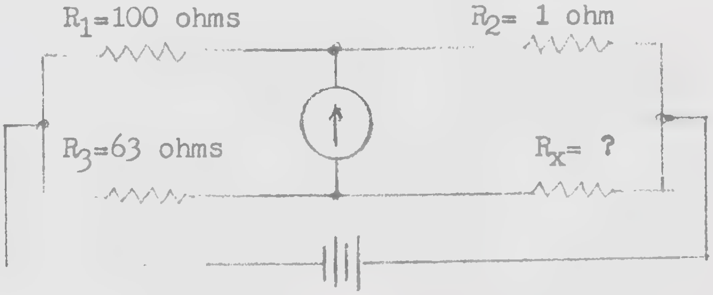
36. A voltmeter consists of
    A. a meter movement without any resistance.
    B. a precision resistor in parallel with a meter movement.
    C. a precision resistor in series with a meter movement.
    D. a galvanometer in parallel with a resistor.

37. In order to measure large currents with a moving coil instrument
    A. the meter must be made more rugged.
    B. an increased number of turns must be put on the moving coil.
    C. shunts must be used.
    D. more dampening is required.

38. A meter movement has a full-scale deflection current of 1 ma and a resistance of 500 ohms. This movement must be used in a current meter for 0 - 1 ampere. What is the value of the shunt required?
    A. 51 ohms.
    B. 2.02 ohms.
    C. 0.5 ohm.
    D. 0.2 ohm.

39. One of the scales on a VOM multimeter is non-linear. This scale is used for
    A. d.c. milliamperes.
    B. ohms.
    C. d.c. volts.
    D. a.c. volts.

40. The value of R_x in the wheatstone bridge circuit is (the bridge is balanced)
    A. 0.37 ohms.
    B. 0.63 ohms.
    C. 370 ohms.
    D. 6300 ohms.



TEST CONSTRUCTION MATRIX POST TEST

topic	knowledge	comprehension	application	total
Electron theory	1, 4, 5	3	2, 6	6
Current, emf resistance Ohm's law	7, 8, 13, 16, 19, 20	9, 11, 12, 14, 17, 21	10, 15, 18, 22, 23, 24	18
Large and small units of measure (ma, μa, kΩ, MΩ)	25, 27,	26, 28	29	5
Wire sizes, CM, resist. of wires	30, 31	33	32, 34, 35	6
Series, parallel, series-parallel circuits Kirchhoff's laws	44, 53	36, 37, 40, 41, 43, 51, 54	38, 39, 42, 45, 46, 47, 48, 49, 50, 52, 55	20
Power, energy	56, 64	57, 61, 63	58, 59, 60, 62, 65, 66	11
Batteries	67, 68	69	70	4
Magnetism	71, 72, 76, 77, 78	73, 74, 75, 79, 80, 82	81	12
Meters	84, 85, 88, 92, 93, 94	83, 90	86, 87, 89, 91, 95	13
Totals	30	29	36	95

ELECTRICITY 12

MULTIPLE CHOICE TEST   Total number of questions: 95

Check this booklet for 16 complete pages

Mark the letter on the answer sheet that corresponds to what you think is the best choice for each question.

NOTE: You will find that for some questions there may be several partly correct choices. You are to select the one choice that you think will best answer the question or complete the statement.

EXAMPLE:

1. What is the most important advantage of a typical lead-acid storage cell when compared to an ordinary dry cell?

   A. It produces a higher voltage.
   B. It can be recharged.
   C. It can deliver a higher current.
   D. It can store more-ampere-hours.

Note, that A,C, and D are partly correct, but B is the most important characteristic of a lead-acid cell.

ANSWER ON THE I.B.M. ANSWER SHEET AS INSTRUCTED - USE H.B. PENCIL

1. The elctrical charges in an atom are distributed in the following manner: Protons __________, neutrons _______, electrons _________.
   A. positive, no charge, negative.
   B. positive, negative, no charge.
   C. no charge, positive, negative.
   D. negative, no charge, positive.

2. Copper has the atomic number 29. This means that the copper atom normally contains
   A. a total of 29 protons and neutrons.
   B. a total of 29 electrons and neutrons.
   C. 29 neutrons and 29 protons.
   D. 29 protons and 29 electrons.

3. An atom of sodium has been disturbed by some outside force. It now contains 11 protons, 12 neutrons, and 10 electrons. This type of atom is called a
   A. neutral atom
   B. negative ion.
   C. positive ion.
   D. normal atom.

4. Electrons that are in the higher energy bands (outermost shells) of metal atoms
   A. are not very tightly held to the atoms.
   B. have the highest electrical charge.
   C. have the lowest electrical charge.
   D. do not participate in the conduction of electric current.

5. In static electrical terms
   A. a negatively charged body has a lack of electrons.
   B. a positively charged body has lost some protons.
   C. like charges attract and unlike charges repel.
   D. none of the above.

6. Two bodies with an equal negative charge are two centimeters apart. What happens to the force between them when the distance is reduced to one centimeter?
   A. The force is doubled.
   B. The force becomes four times as great.
   C. The force is reduced to one half
   D. The force remains the same.

7. In an electric circuit electrons are considered to move from
   A. left to right.
   B. right to left.
   C. negative to positive.
   D. positive to negative.

8. The principal effects of current are
   A. magnetism and conductance.
   B. resistance and heat.
   C. conductance and resistance.
   D. magnetism and heat.

9. When an electric current is compared to a completely closed pipe system, electric current should be compared to
   A. pressure.
   B. the amount of water in the pipe system.
   C. the amount of water flowing past any given point per second.
   D. the pressure difference before and behind the pump.

10. A flow of 4 coulomb in 2 seconds is measured in a circuit. The current in that circuit is
    A. 8 amp.
    B. 4 amp.
    C. 2 amp.
    D. $\frac{1}{2}$ amp.

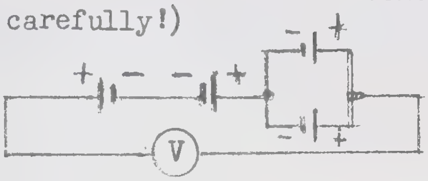
11. Which statement would best describe the flow of current in a metal conductor?
    A. All atoms in a conductor are moved simultaneously in the same direction.
    B. Electrons are torn loose from their atoms and pushed along the conductor with the speed of light.
    C. Electrons jump from atom to atom thereby moving in one general direction.
    D. Electrons are pushed into one end of the conductor and the same electrons come out at the other end.

12. In order for current to flow in a circuit there must be
    A. an open path across a potential difference.
    B. a closed path with a zero potential difference.
    C. an open path across a zero potential difference.
    D. a closed path between a potential difference.

13. The volt is a measure of
    A. the intensity of electron flow past a given point.
    B. the ability of a conductor to allow electron flow.
    C. the potential difference between two points.
    D. the opposition to electron flow.

14. Six cells of 1.5 volts each are connected in parallel. The output voltage of this connection is
    A. 1.5 volts.
    B. 3 volts.
    C. 9 volts.
    D. 12 volts.

15. Four 1.5-volt dry cells are connected as shown. The voltmeter V will read (look at the diagram carefully!)
    A. 6 volts.
    B. 3 volts.
    C. 1.5 volts.
    D. 0 volt.



16. The major effect of resistance in an electric circuit is
    A. the creation of electric current.
    B. the creation of electric pressure.
    C. the limitation of electric current.
    D. the limitation of electric pressure.

17. When referring to a circuit's conductance, you visualize the degree to which the circuit
    A. opposes the rate of current flow.
    B. opposes the rate of voltage changes.
    C. permits or conducts current flow.
    D. permits or conducts voltages.

18. The conductance of a 90-ohm resistor is
    A. 90,000 mhos.
    B. 11.1 mhos.
    C. 0.9 mho.
    D. 0.011 mho.

19. A short circuit will cause
    A. the voltage to increase.
    B. the resistance to increase.
    C. the current to increase.
    D. the voltage to decrease.

20. In a d.c. circuit the current is
    A. directly proportional to voltage and inversely proportional to the resistance.
    B. directly proportional to the resistance and inversely proportional to the voltage.
    C. indirectly proportional to the resistance and inversely proportional to the conductance.
    D. indirectly proportional to the resistance and inversely proportional to the voltage.

21. When the voltage applied to a circuit is doubled and the resistance is also doubled, the resultant current is
    A. double the original.
    B. one-half the original.
    C. one quarter the original.
    D. the same as the original.

22. A lamp is connected to a source of 110 v and draws a current of 0.9 a. What is the resistance of the lamp?
    A. 12.22 ohms.
    B. 122.2 ohms.
    C. 0.008 ohm.
    D. 0.08 ohm.

23. A resistor of 50 ohms is connected to 125 volts. What current will it draw?
    A. 6000 amps.
    B. 6 amps.
    C. 2.5 amps.
    D. 0.4 amp.

24. A relay with a coil of 250 ohms requires a d.c. of 0.2 a for its operation. It must be connected to a d.c. source of
    A. 1250 v.
    B. 125 v.
    C. 80 v.
    D. 50 v.

25. One megohm is the equivalent of
    A. 1/1,000,000 ohm.
    B. 1/1000 ohm.
    C. 1000 ohms.
    D. 1,000,000 ohms.

26. One thousand microamps is the equivalent of
    A. 1 amp.
    B. 1/1000 amp.
    C. 1/1,000,000 amp.
    D. none of these.

27. 18 kilovolt can also be expressed as
    A. 18×10^{-3}
    B. 1.8×10^{2}
    C. 1.8×10^{3}
    D. 1.8×10^{4}

28. A current of 3.3×10^{-5} amps could also be expressed as
    A. 3.3 micro-amps.
    B. 33 micro-amps.
    C. 0.33 milliamps.
    D. 3.3 milliamps.

29. The voltage required to cause a current of 50 microamps through a resistance of 150 kilohms is
    A. 3 v.
    B. 7.5 v.
    C. 3000 v.
    D. 7500 v.

30. Select the answer that shows the materials ordered in their ability to conduct electric current. The best conductor first and the one offering the highest resistance last.
    A. Gold, silver, copper, aluminum.
    B. Silver, copper, aluminum, iron.
    C. Copper, silver, gold, nickel.
    D. Silver, aluminum, copper, iron.

31. Which of the following methods is correct for finding the circular mil (CM) area of an electrical conductor?
    A. (diameter in mils)^2 x 3.14
    B. (diameter in mils)^2
    C. (diameter in inches)^2 x 3.14
    D. (diameter in millimeter)^2

32. In a length of wire the resistance is
    A. proportional to the length and unaffected by the cross-section.
    B. inversely proportional to length and cross-section area.
    C. directly proportional to length and cross-section area.
    D. directly proportional to length and inversely proportional to the cross-section area.

33. A copper wire conductor with 0.2 inch diameter has an area of
    A. 200 circular mils.
    B. 400 circular mils.
    C. 20,000 circular mils.
    D. 40,000 circular mils.

34. A number 10 AWG wire has a cross-sectional area of almost 10,400 CM. What is the resistance of 200 ft. of this wire? (K for copper: 10.4)
    A. 0.028 ohms.
    B. 0.2 ohms.
    C. 0.52 ohms.
    D. 5.2 ohms.

35. A copper coil in a transformer has a resistance of 10 ohms at 20° C. After the transformer operated for some time, the temperature of the coil rose to 40° C. What is the resistance of the coil at that temperature? (Temperature coefficient for copper is 0.004.)
    A. 9.8 ohms.
    B. 10.08 ohms.
    C. 10.8 ohms.
    D. 14.8 ohms.

36. Inserting additional resistance into a series circuit will
    A. cause additional current flow.
    B. increase the voltage drop across the source.
    C. increase the power loss in the circuit.
    D. reduce the current in the circuit.

37. In a series circuit of three resistors, the amount of current flowing through one resistor
    A. depends upon the resistance of that resistor.
    B. depends upon the position of that resistor in the circuit.
    C. is the same as the current flowing through the others.
    D. may be different from the current through the others.

38. In a series circuit an electric bell is 5.1 ohms, the connecting wires are 1.4 ohms and a resistor is 0.3 ohms. The total resistance is
    A. .021 ohms.
    B. 6.8 ohms.
    C. 16 ohms.
    D. 22 ohms.

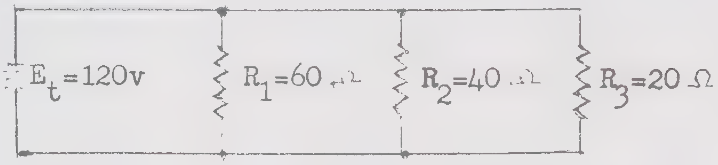
39. How much current will be drawn by 8 - 100-ohm resistors connected in parallel across a 20 volt line?
    A. 40 amps.
    B. 1.6 amps.
    C. 0.2 amps.
    D. 0.0125 amp.

40. Resistance of 100 ohms, 200 ohms, 300 ohms, and 1 megohm are connected in parallel. The total resistance is
    A. more than 1 megohm.
    B. about one megohm.
    C. about 600 ohms.
    D. less than 100 ohms.

41. Two resistors of 250 ohms and 350 ohms are connected in parallel. The total resistance of this connection is very close to
    A. 146 ohms.
    B. 187 ohms.
    C. 300 ohms.
    D. 600 ohms.

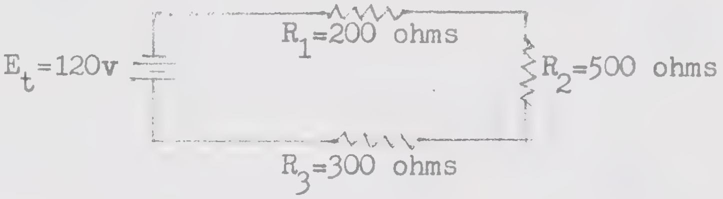
42. Three resistors are connected in parallel. One has 10 ohms resistance, another 30 ohms, and the third 60 ohms. The total resistance is
    A. 7.9 ohms.
    B. 5.6 ohms.
    C. 6.67 ohms.
    D. 100 ohms.

43. In the circuit below the voltages applied to R_1, R_2, and R_3 in their respective order are
A. 60v, 40v, 20v.
B. 2v, 3v, 6v.
C. 20v, 40v, 60v.
D. 120v, 120v, 120v.

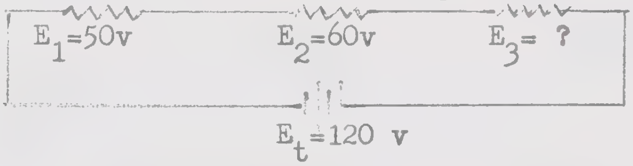


44. Kirchhoff's voltage law in its basic form should only be used in
A. series circuits.
B. parallel circuits.
C. series parallel circuits.
D. d. c. circuits.

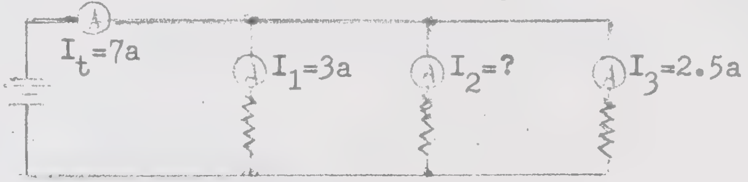
45. In the circuit below the voltage drop V_2 in the resistor R_2 is
A. 24 v.
B. 36 v.
C. 60 v.
D. 120 v.



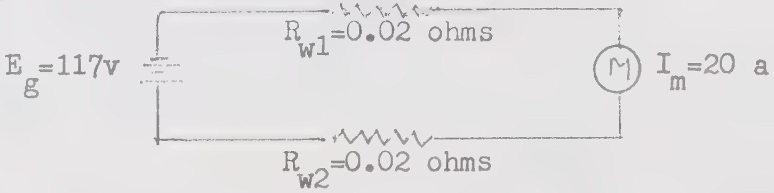
46. In the circuit below what is the voltage drop across R_3?
A. zero volts.
B. 10 volts.
C. 20 volts.
D. 120 volts.



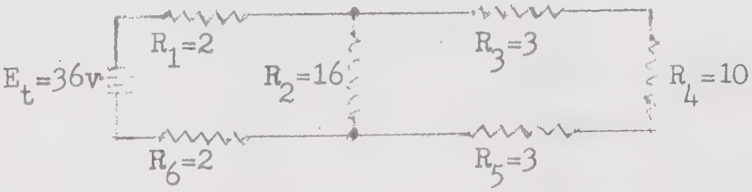
47. In the circuit below the total current is 7 amps. What is the current in R_2?
A. zero.
B. 1.5 amp.
C. 5.5 amps.
D. 7 amps.



48. The generator G in the connection below produces 117 v. The motor M draws a current of 20 a. The resistance of each line wire is 0.02 ohm. What is the voltage at the motor?
A. 117 v.
B. 116.96 v.
C. 116.6 v.
D. 116.2 v.

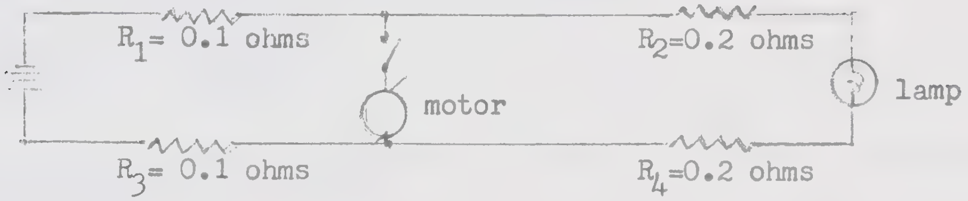


49. The total resistance of the circuit below is
A. 12 ohms
B. 16.5 ohms
C. 18.7 ohms
D. 22 Ohms

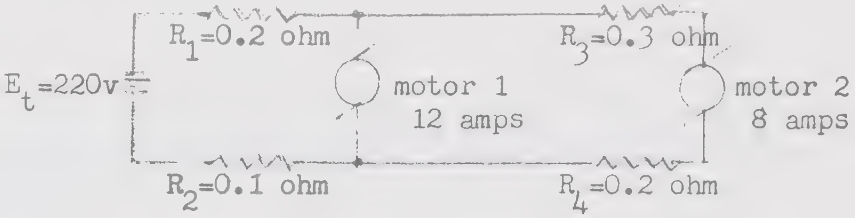


50. The current in resistor R_4 in the diagram of the previous question (#49) is
A. 0.8 amp.
B. 1.5 amps.
C. 3 amps.
D. 6 amps.

51. Which of the following statements is true for the diagram below? When the motor M is started
A. more current flows through the lamp.
B. the line resistance R_2 and R_4 increases.
C. the voltage drops across R_1 and R_3 decrease.
D. less current will flow through the lamp.

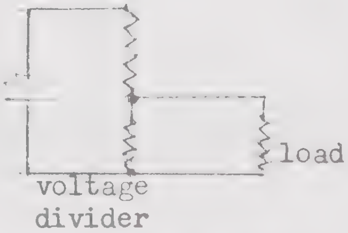


52. The voltage across motor two in the two-wire circuit below is
A. 215.2 v.
B. 212 v.
C. 210.4 v.
D. 207.2 v.

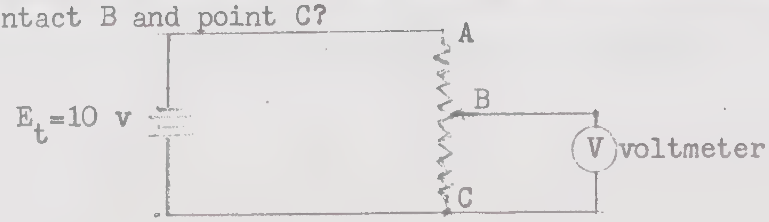


53. A device that has three active terminals and can be used as a voltage divider is called a ____________________ . A device that has two active terminals and can be used to regulate current going to a motor or other load is called a ____________________.
A. rheostat, potentiometer.
B. potentiometer, rheostat.
C. rheostat, variable resistor.
D. variable resistor, potentiometer.

54. When the load on a voltage divider increases
A. the voltage across the load increases.
B. the resistance of the load increases.
C. the equivalent resistance increases.
D. All of the above statements are incorrect.



55. A 500-ohm potentiometer is connected to a 10-volt source as shown below. The voltmeter (a VTVM) reads 7 volts. What is the resistance between the slider contact B and point C?
A. 150 ohms.
B. 350 ohms.
C. 493 ohms.
D. 500 ohms.



56. Select the answer that correctly shows the three basic formulas for calculating electric power.
   A. $P=EI$, $P=I^2R$, $P=\frac{E}{R}$.
   B. $P=\frac{E^2}{I}$, $P=IR$, $P=EI$.
   C. $P=I^2E$, $P=\frac{I^2}{R}$, $P=I^2R$.
   D. $P=I^2R$, $P=\frac{E^2}{R}$, $P=EI$.

57. Three resistors of 2, 4, and 6 ohms respectively are connected in parallel. Which resistor would absorb the most power?
   A. It will be the same for all resistors.
   B. The 6- ohm resistor.
   C. The 4-ohm resistor.
   D. The 2-ohm resistor.

58. A car headlight draws a current of 5.5 amp at 12 volts. The wattage of the lamps is very close to
   A. 2.2 watts.
   B. 17.5 watts.
   C. 66 watts.
   D. 78 watts.

59. A current of 5 amps is flowing through a 50-ohm resistance. The power dissipated is
   A. 1250 watts.
   B. 250 watts.
   C. 125 watts.
   D. 25 watts.

60. When a light operates from a 24-volt supply and uses 96 watts of power, the current flowing through the light must be
   A. 0.25 a.
   B. 4 a.
   C. 16 a.
   D. 72 a.

61. A 120-volt electric outlet is protected by a 10-amp fuse. Three devices rated at 500, 200, and 400 watts are connected in parallel to this outlet. The fuse will
   A. burn out immediately.
   B. not burn out.
   C. burn out after a short period of time.
   D. burn out and restore the circuit automatically.

62. What is the maximum voltage that should be applied to a 500-ohm 5-watt resistor?
   A. 10 v.
   B. 50 v.
   C. 100 v.
   D. 2500 v.

63. An electric heater uses 1500 watts of electric power when a current of 12 amps flows through the heater. What will be the power consumption when the current is reduced to 6 amps, provided the resistance of the heater does not change?
A. 3000 watts.
B. 1500 watts.
C. 750 watts.
D. 375 watts.

64. What is the most commonly used unit of electric energy?
A. Horsepower.
B. Watt.
C. Kilowatt.
D. Kilowatt-hour.

65. A television receiver rated at 120 volts and 2 amperes is operated for 100 hours. What is the cost of operating this set at 3¢ per kilowatthour?
A. $7.20
B. $3.60
C. $2.40
D. $0.72

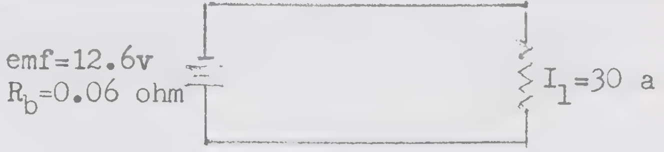
66. An electric water heater is designed for 230 volts. At this voltage it will heat the total water content to the desired temperature in $1\frac{1}{2}$ hours. This water heater is connected to 115 volts. How long will it take for the water to be heated to the desired temperature?
A. 6 hrs.
B. 3 hrs.
C. $1\frac{1}{2}$ hrs.
D. $\frac{3}{4}$ hrs.

67. Electrical charges move through the electrolyte of an electrochemical cell by means of
A. free electrons.
B. ions.
C. molecules.
D. complete atoms.

68. The electrolyte of a lead-acid wet cell is
A. sal amoniac.
B. manganese dioxide.
C. sulfuric acid.
D. muriatic acid.

69. If the load resistor across the terminals of a battery is made smaller in ohms value, the voltage drop across the internal resistance
A. decreases
B. becomes zero.
C. increases.
D. remains the same.

70. The total internal resistance of the 12.6-volt battery in the circuit below is 0.06 ohms. What is the terminal voltage of the battery when a load current of 30 amps is drawn from the battery?
A. 12.6 v.
B. 12.42 v.
C. 12 v.
D. 10.8 v.



71. In a bar magnet magnetic lines of force are thought to have the direction of
A. south to north outside the magnet and north to south inside.
B. north to south outside the magnet and south to north inside.
C. south to north both inside and outside the magnet.
D. north to south both inside and outside the magnet.

72. The theory of magnetism states that magnetic materials are different from ordinary materials because they form small magnetic units that behave like tiny bar magnets. The name of these units is
A. dipole atoms.
B. dipole molecules.
C. magnetic atoms.
D. domains.

73. Soft iron is most suitable for use in a
A. permanent magnet.
B. natural magnet.
C. temporary magnet.
D. magneto.

74. The permeability of a substance is
A. a measure of its ability to resist magnetism.
B. a measure of its ability to concentrate lines of force.
C. dependent upon its size.
D. dependent upon its shape.

75. If magnetic circuits were thought to be analogous to electric circuits, then
A. flux could be thought to be similar to current.
B. reluctance could be thought to be similar to resistance.
C. mmf could be thought of to be similar to emf.
D. all of the above.

76. In what material is retentivity most apparent?
A. Hard steel.
B. Soft iron.
C. Copper.
D. Wood.

77. Insertion of a soft iron core into a current carrying coil will
A. destroy the magnetic field.
B. increase flux density.
C. decrease flux density.
D. not affect the magnetic field.

78. The strength of an electromagnet depends on a number of factors. What are the more important ones of these factors?
    A. Current, number of turns, shape and type of core material.
    B. Voltage, size of wire, length and diameter of the coil.
    C. Current, number of turns, spacing of turns and layer.
    D. Ratio of diameter to length of the coil and the power used.

79. A wire penetrating this page with a current flow from negative to positive downward into the page has a magnetic field that is
    A. counterclockwise and in a plane parallel to this page.
    B. clockwise and in a plane parallel to this page.
    C. parallel to the wire and going into the page.
    D. parallel to the wire and coming up from the page.

80. The permeability of a magnetic material becomes lower when the magnetizing force increases, because of the effect of
    A. hysteresis.
    B. eddy currents.
    C. saturation.
    D. coercive force.

81. If an iron core is inserted partly into a coil and a current is applied to the coil, the core will be drawn into the coil in an effort to
    A. increase the reluctance of the field.
    B. decrease the length of the magnetic circuit.
    C. reduce the permeability of the circuit.
    D. increase the residual effect.

82. When two parallel conductors carrying current in the same direction are placed side by side, the magnetic fields produced by both
    A. cancel each others field.
    B. push each other apart.
    C. have no effect on each other.
    D. encircle both conductors drawing them together.

83. The basic moving coil measuring instrument measures
    A. the effect of electric current by interaction of a permanent magnet with an electromagnetic coil.
    B. the effect of an electric current by measuring the heat developed by that current.
    C. the effect of an emf by measuring the interaction of two opposing electrostatic fields.
    D. the effects of the combination of current and emf by measuring the interaction of a stationary and a movable electromagnetic field.

84. One disadvantage of the moving coil (D'Arsonval) instrument is
    A. it is too sensitive.
    B. it operates on d. c. only.
    C. the permanent magnet tends to weaken.
    D. it is too delicate.

85. A voltmeter consists of
    A. a meter movement without any resistance.
    B. a precision resistor in parallel with a meter movement.
    C. a precision resistor in series with a meter movement.
    D. a precision resistor in parallel with a galvanometer.

86. A d.c. voltmeter has an internal resistance of 1000 ohms and a full-scale deflection of 10 volts. To increase the range of this voltmeter to 100 volts, the multiplier resistance to be added should be
    A. 5000 ohms.
    B. 7000 ohms.
    C. 9000 ohms.
    D. 10,000 ohms.

87. A meter movement has a full-scale-deflection current of 1 ma and an internal resistance of 100 ohms. What is the value of the voltage multiplier required to convert this movement into a voltmeter for 0 to 100 volts?
    A. 900 ohms.
    B. 9,900 ohms.
    C. 99,900 ohms.
    D. 100,000 ohms.

88. A voltmeter will give the most accurate readings in low-current circuits when it has
    A. a low internal resistance.
    B. a low ohms-per-volt rating.
    C. a high ohms-per-volt rating.
    D. a movement of low resistance.

89. A voltmeter with an internal resistance of 500 kilo-ohm at the 250-volt range has a sensitivity rating of
    A. 500,000 ohms/volt.
    B. 20,000 ohms/volt.
    C. 5000 ohms/volt.
    D. 2000 ohms/volt.

90. In order to measure large currents with a moving coil movement,
    A. the meter must be made more rugged.
    B. an increased number of turns must be put on the moving coil.
    C. shunts must be used.
    D. more dampening is required.

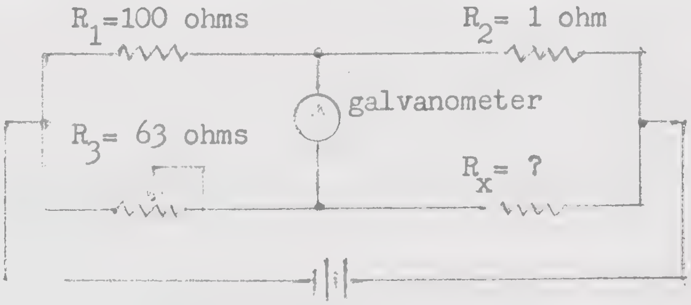
91. A meter movement has a full-scale-deflection current of 1 ma and a resistance of 500 ohms. This movement must be used in a current meter for 0 to 1 amp. What is the value of the required shunt?
    A. 51 ohms.
    B. 2.02 ohms.
    C. 0.5 ohms.
    D. 0.2 ohms.

92. One of the scales on a VOM multimeter is non-linear. This scale is used for.
   A. ohms.
   B. a. c. volts.
   C. d. c. volts.
   D. d. c. milliamps.

93. The purpose of the zero adjust on an ohmmeter is to
   A. compensate for voltage fluctuations in the battery.
   B. correct variations due to temperature changes.
   C. compare readings with a known precision resistor.
   D. to change the range setting.

94. For very accurate resistance measurements we usually use
   A. a shunt type ohmmeter.
   B. a megohmmeter.
   C. a wheatstone bridge circuit.
   D. a precision VOM.

95. The value of R_x in the wheatstone bridge circuit below is (the bridge is balanced).
   A. 0.37 ohms.
   B. 0.63 ohms.
   C. 370 ohms.
   D. 6300 ohms.



TEST CONSTRUCTION MATRIX RETENTION TEST

topic	knowledge	comprehension	application	total
Electron theory	2, 3, 4	1, 5	6	6
Ohm's law	8, 15	10, 11	7, 9, 12, 13, 14	9
Wire sizes	16, 20	17,	18, 19	5
Series, parallel, series-parallel circuits	21, 22, 23, 26	29, 30, 31, 35	24, 25, 27, 28, 32, 33, 34	15
Power, energy	36	37	38, 39, 40, 41	6
Batteries	43	42, 44		3
Magnetism	45, 46, 49, 50	48, 51, 52	47	8
Meters	53, 58	54, 56, 57, 59	55, 60	8
totals	19	19	22	60

ELECTRICITY 12

MULTIPLE CHOICE TEST Total number of questions: 60

Check this booklet for 10 complete pages

Mark the letter on the answer sheet that corresponds to what you think is the best choice for each question.

NOTE: You will find that for some questions there may be several partly correct choices. You are to select the one choice that you think will best answer the question or complete the statement.

EXAMPLE:

1. What is the most important advantage of a typical lead-acid storage cell when compared to an ordinary dry cell?

   A. It produces a higher voltage.
   B. It can be recharged.
   C. It can deliver a higher current.
   D. It can store more-ampere-hours.

Note, that A,C, and D are partly correct, but B is the most important characteristic of a lead-acid cell.

ANSWER ON THE I.B.M. ANSWER SHEET AS INSTRUCTED - USE H.B. PENCIL

1. The neutrons in the nucleus of an atom give it
   A. a positive charge.
   B. a negative charge.
   C. mass and weight only.
   D. dimension and shape.

2. The atoms of a positively charged object have
   A. more electrons than protons.
   B. an equal number of electrons and protons.
   C. fewer electrons than protons.
   D. extra neutrons in the nucleus.

3. Of the following the best conductor is
   A. aluminum.
   B. copper.
   C. gold.
   D. silver.

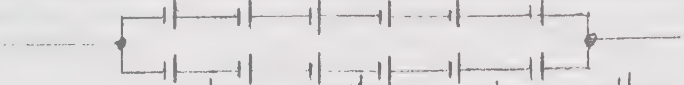
4. Metals are good conductors because metal atoms
   A. have more electrons than other atoms.
   B. do not hold the electrons in the highest energy band (outermost shell) too tightly.
   C. have an excess of electrons.
   D. have more electrons in the highest energy band (outermost shell).

5. Which statement about current flow in a conductor is most correct?
   A. The electric push that causes electrons to move is transmitted with the speed of light, but the electrons themselves travel much slower.
   B. Electrons are "pumped into the conductor at the negative end and travel with the speed of light until they reach the other end.
   C. Electrons travel slower in a thinner wire.
   D. Electrons never leave their atoms, it is the movement (change of position) of the electrons within their atoms that constitutes current.

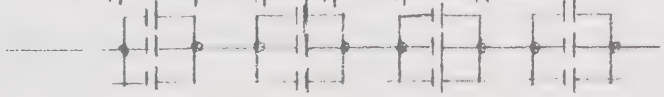
6. An ammeter measures a current flow of 3 amps. If this current continues to flow for 10 seconds, the electrical charge passing through the ammeter in this time span will be
   A. 30 coulombs.
   B. 10 coulombs.
   C. 3.33 coulombs.
   D. 0.3 coulomb.

7. Twelve 1.5-volt dry cells are available and a voltage of 6 volts is required. Which of the connections do you consider the best?

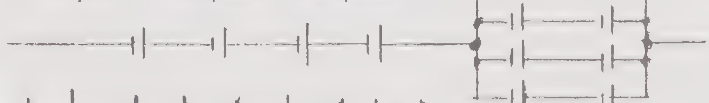
   A.



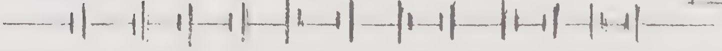
   B.



   C.



   D.



8. Conductance is a term whose meaning is
   A. the equivalent of resistance.
   B. the inverse of resistance.
   C. the equivalent of electromotive force.
   D. the opposite of electromotive force.

9. An electric circuit that has a conductance of 0.01 mho, has a resistance of
   A. 100 ohms.
   B. 10 ohms.
   C. 0.99 ohm.
   D. 0.01 ohm.

10. An electrical device has become defective. The defect is an open circuit. When the resistance of this device is measured it will be
    A. infinity.
    B. a low ohms value.
    C. zero.
    D. impossible to determine.

11. To keep the current in a circuit constant when the emf is increased the resistance must be
    A. kept proprotional to the current.
    B. decreased in the same proportions as the emf is increased.
    C. kept inversely proportional to the current.
    D. increased in the same proportion as the emf is increased.

12. The resistance required to limit the current to 25 ma in a 30-volt circuit is
    A. 0.75 ohm.
    B. 1.2 ohm.
    C. 750 ohms.
    D. 1200 ohms.

13. A heater has a resistance of 240 ohms. It is connected to 80 volts. The current will be
    A. 19,200 amps.
    B. 3 amps.
    C. 0.33 amps.
    D. 0.30 amps.

14. A current of 2.5×10^{-4} amps is measured in a circuit with a resistance of 5×10^{5} ohms. The voltage applied to this circuit must be
    A. 0.05 volt.
    B. 0.125 volt.
    C. 0.2 volts.
    D. 125 volts.

15. 0.85 megohm can also be expressed as
    A. 8.5×10^{6} ohms.
    B. 8.5×10^{5} ohms.
    C. 8.5×10^{2} ohms.
    D. 8.5×10^{-7} ohms.

16. A number 16 conductor is
    A. larger than a # 14 conductor.
    B. smaller than a # 14 conductor.
    C. not very much different from a # 14 conductor.
    D. twice as large as a # 14 conductor.

17. A lenth of copper wire has a resistance of 10 ohms. A similar wire with the same length but of one-half the cross-sectional area will have a resistance of
    A. 40 ohms.
    B. 20 ohms.
    C. 5 ohms.
    D. 2.5 ohms.

18. A copper conductor has a cross-sectional area of 5,200 CM and is 1000ft. long. What is the resistance of the wire (K for copper: 10.4)
    A. 0.5 ohm.
    B. 2 ohms.
    C. 5.2 ohms.
    D. 50 ohms.

19. A circular conductor with a cross-sectional area of 40,000 CM has a diameter of
    A. 4 inches.
    B. 2 inches.
    C. 0.63 inch.
    D. 0.2 inch.

20. The resistance of a lamp is measured with an ohmmeter and found to be 60 ohms. Under actual operating conditions this resistance will likely be
    A. higher.
    B. lower.
    C. zero.
    D. the same.

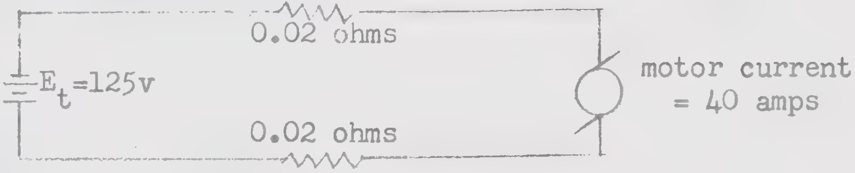
21. In a series circuit the total current is
    A. the sum of the currents in the individual resistors.
    B. the same as the current in any part of the circuit.
    C. equal to zero at the positive end of the circuit.
    D. highest at the negative end of the circuit.

22. A circuit of unequal resistances in series is connected to a power supply;
    A. the various currents in the circuit are decided by the values of the resistances in which they flow.
    B. the sum of the voltages across each of the resistances is equal to the power supply voltage.
    C. the voltage across each individual resistor is equal to the power supply voltage.
    D. all resistances have the same voltage across them.

23. The voltage drop in a resistance is equal to
    A. amps times resistance.
    B. voltage times resistance.
    C. voltage times amps.
    D. voltage divided by resistance.

24. In a burglar alarm system a buzzer with a 12 ohm resistance is connected in series with an 8-ohm resistor. The combined resistance of all connecting wires is 0.75 ohm. What is the total resistance of the circuit?
    A. 20.75 ohms.
    B. 6.55 ohms.
    C. 5.95 ohms.
    D. 0.75 ohms.

25. The voltage at the motor in the diagram is
    A. 125 v
    B. 124.6 v
    C. 124.2 v
    D. 123.4 v



26. The total resistance of a parallel circuit is
    A. less than the lowest resistance.
    B. more than the highest resistance.
    C. the sum of all individual resistances.
    D. the product of the individual resistances divided by 10.

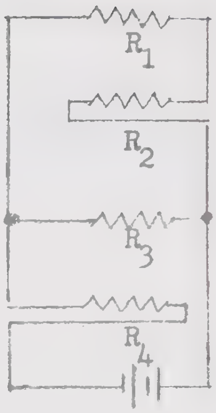
27. Three resistors of 40, 60, and 120 ohms are connected in parallel. The total resistance of this circuit is
    A. 20 ohms.
    B. 22 ohms.
    C. 26 ohms.
    D. 220 ohms.

28. Six lamps of 180 ohms each are connected in parallel. The total resistance of this connection is
    A. 1080 ohms.
    B. 180 ohms.
    C. 30 ohms.
    D. 3.33 ohms.

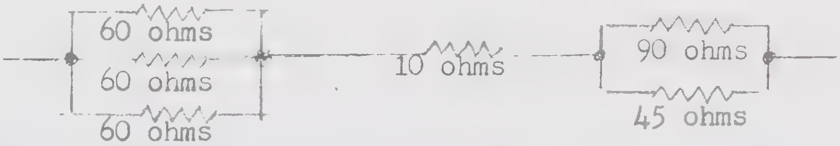
29. If three resistors are connected in parallel what is the relationship of the voltage across each resistor with that of the source?
    A. The voltages are proportional to the resistances.
    B. The voltages are inversely proportional to the resistances.
    C. All voltages are the same.
    D. The voltage across each resistor is proportional to the current through that resistor.

30. If one branch of a parallel circuit opens, the main line current
    A. increases.
    B. is unchanged.
    C. decreases.
    D. drops to zero.

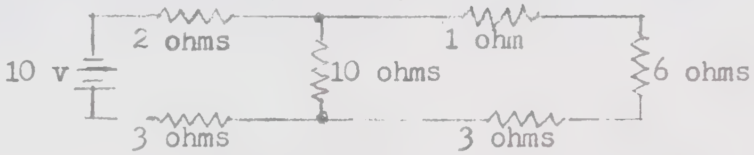
31. Which statement is correct for the circuit below?
    A. R_1 and R_2 are in parallel; R_3 and R_4 are in parallel; both parallel connections are in series.
    B. R_1 and R_2 are in series and this series string is in parallel with R_3; R_4 is in series with this connection.
    C. All resistors are in series.
    D. All resistors are in parallel.



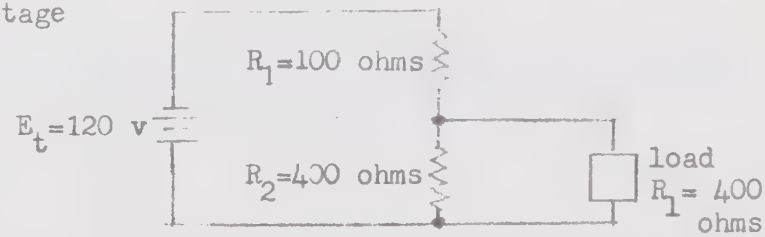
32. What is the total resistance of the series-parallel circuit below?
    A. 5.45 ohms.
    B. 60 ohms.
    C. 115 ohms.
    D. 325 ohms.



33. What is the total current in the circuit below?
    A. 1.14 amp.
    B. 1 amp.
    C. 0.667 amp.
    D. 0.4 amp



34. In the voltage divider circuit below the resistance of the load is 400 ohms. The voltage at the load is
    A. 120 v.
    B. 96 v.
    C. 80 v.
    D. 60 v.



35. In the voltage divider circuit of the foregoing question, when the resistance of the load is decreased, the voltage across R_2 will
    A. decrease.
    B. increase.
    C. remain the same.
    D. become graeter than the voltage across the load.

36. The equation that correctly calculates resistance from power and emf is
A. $R = \frac{E}{I}$
B. $R = \frac{E}{P}$
C. $R = P \times I$
D. $R = \frac{E^2}{P}$

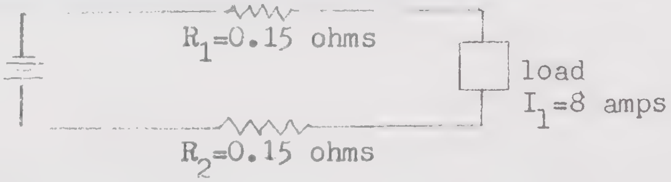
37. If the resistance is held constant, what happens to the power when the current is doubled?
A. Power is doubled.
B. Power increases four times.
C. Power is halved.
D. Power is divided by four.

38. A 20-watt lamp is connected to a 120-volt circuit. The current in the lamp is
A. 16.2 amps.
B. 6 amps.
C. 0.167 amps.
D. 0.6 amps.

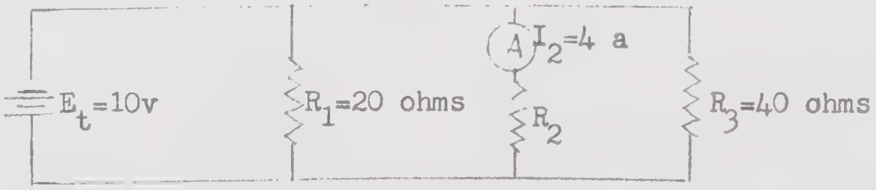
39. An electric heater is connected to 120 volts and draws a current of 10 amps. The heater is connected for a total of 40 hours. The cost of electrical energy is 1½¢ per kilowatthour. What is the cost of operating the heater?

A. $18.00
B. $4.80
C. $1.80
D. $0.72

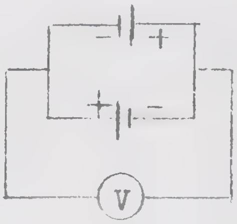
40. What is the power loss in the line wires (R_1 and R_2)in the circuit below?
A. 1.2 watts.
B. 2.4 watts.
C. 9.6 watts.
D. 19.2 watts.



41. If the resistors in the circuit below are all rated at 25 watt, which resistor would overheat?
A. R_1
B. R_2
C. R_3
D. all



42. Which of the ststements would best describe the condition of the circuit below? (Look at the diagram carefully!)
    A. The voltmeter will read 3 v.
    B. The voltmeter will read 1.5 v, but the battery life is longer than only one cell.
    C. The voltmeter will read zero. The emf's of the two cells cancel each other.
    D. The voltmeter will read zero. There is a short circuit in the battery connection.



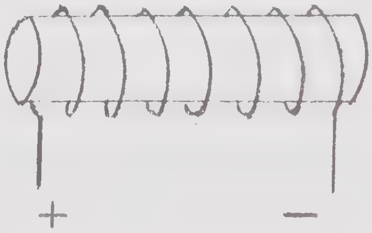
43. The dry cell battery is a
    A. secondary cell.
    B. polarized cell.
    C. primary cell.
    D. voltaic cell.

44. A high internal resistance is undesirable in a battery because it
    A. is the cause of polarization.
    B. allows the battery to discharge even when no load is connected.
    C. contributes to the deterioration of the electrodes and the electrolyte.
    D. reduces the output voltage when a large load current flows.

45. The direction of lines of force around a bar magnet is considered to be
    A. out of the south pole into the north pole.
    B. out of the north pole into the south pole.
    C. equally out of either pole into the other.
    D. from one magnet to another magnet only.

46. If the direction of the current through a conductor is known, and it is considered to be from negative to positive, the direction of the magnetic field around the conductor may be found by
    A. the right-hand rule.
    B. the left-hand rule.
    C. Fleming's rule.
    D. Faraday's rule.

47. In the current-carrying coil shown in the diagram, the field will arrange itself so that
    A. lines of force have a counterclockwise direction around the coil when the coil is viewed from the right.
    B. Lines of force have a clockwise direction around the coil when the coil is viewed from the right.
    C. a magnetic north pole will form at the left of the coil.
    D. a magnetic north pole will form at the right of the coil.



48. Flux in a magnetic circuit can be compare with ______________ in an electric circuit.
A. voltage
B. current
C. resistance
D. conductance

49. The unit for flux density, the gauss, is
A. one line of force per square centimeter.
B. 10^2 lines per square meter.
C. 10^2 lines per square inch.
D. equal to 10^8 weber.

50. The weber, a unit of flux used in the mks system, is eqal to
A. 10^3 lines of force.
B. 10^5 lines of force.
C. 10^6 lines of force.
D. 10^8 lines of force.

51. Hysteresis losses are due to the
A. constant reversal of magnetic lines of force in a magnetic material.
B. leakage between the windings of an electromagnet.
C. use of direct current in the primary coil of a transformer.
D. none of the above are correct.

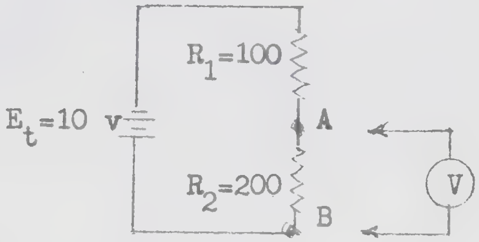
52. Magnetic saturation of a material is the condition when
A. almost all domains are lined up in the same direction.
B. almost all atoms are formed into magnetic domains.
C. almost all domains are permanently held in the same direction.
D. magnetic domains are so closely packed that there is no unmagnetic space between them.

53. A moving-coil or D'Arsonvel movement measures the value of
A. a direct current flowing through it.
B. an alternating current flowing through it.
C. both a.c. and d.c. flowing through it.
D. either a.c. or d.c. power connected to it.

54. If the full-scale deflection current of a meter movement is 1 ma. and the internal resistance of the movement is 100 ohms, what is the maximum voltage that can be measured with this meter using a voltage multiplier of 99,900 ohms?
A. 1 volt.
B. 10 volts.
C. 100 volts.
D. 1000 volts.

55. A voltmeter with the sensitivity of 4000 ohms/volt is switched to the 250-volt range. What is the input (internal) resistance at this range?
A. 16 ohms.
B. 100 ohms.
C. 100,000 ohms.
D. 1,000,000 ohms.

56. A voltmeter with the sensitivity of 1000 ohms/volt is used to measure the voltage wwtween A and B in the circuit below. The measured voltage is considerably lower than the calculated voltage. This is likely due to
A. using a range setting that is too low.
B. using a range setting that is too high.
C. the loading effect of the voltmeter on the circuit.
D. failure to set the zero adjust.

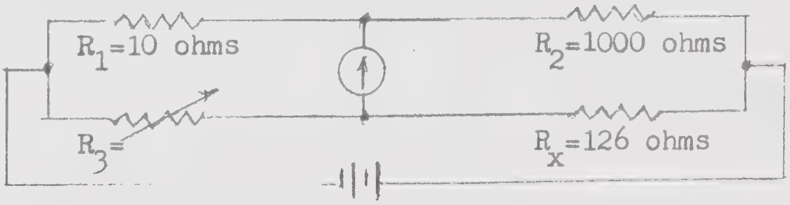


57. A moving-coil (D'Arsonval) movement is used as an ammeter. To increase the range we must
A. increase the resistance of the shunt.
B. decrease the resistance of the shunt.
C. increase the resistance of the multiplier.
D. decrease the resistance of the multiplier.

58. To double the current range of a 5-amp current meter with an internal resistance of 0.2 ohm, the shunt resistance must be
A. 0.2 ohms.
B. 0.4 ohms.
C. 2.5 ohms.
D. 10 ohms.

59. In order to construct an ohmmeter that can be used for measurements of very high resistances it would be desirable to use
A. a battery with a higher voltage.
B. a meter with a very small full-scale-deflection current.
C. an internal(fixed) resistor of low value.
D. a combination of A and B.

60. In order to balance the wheatstone bridge below, the adjustable resistance R_3 must be set to
A. 0.793 ohm.
B. 1.26 ohms.
C. 126 ohms.
D. 874 ohms.



ATTITUDE QUESTIONNAIRE CONSTRUCTION MATRIX

	item numbers	
	positive items	negative items
General Effectiveness (as viewed by the student)	2	4
Time to learn (as viewed by the student)	6	16
Understanding (as viewed by the student)	9	14
General Preference	12	1
Interesting (less boring)	3	5
Better able to Concentrate	7	10
Easier Learning	15	11
Feeling of Accomplishment (Positive reinforcement)	13	8
Total Items	8	8

QUESTIONNAIRE ON PROGRAMED INSTRUCTIONAL MATERIAL

The objective of this questionnaire is to compare programed instruction with the typical lecture-discussion type classroom presentation.

	strongly agree	agree	no opinion	disagree	strongly disagree
1. I would prefer regular lecture-discussion type classroom presentation instead of programed material.					
2. I think programed materials would produce better learning in some other subjects taught in this school if it would be used to partially replace some of the present methods.					
3. I find working through programed material more interesting than typical classroom presentations.					
4. I think that for learning basic electrical theory a lecture-discussion presentation would be more effective than programed material.					
5. I often get bored when I work through a programed unit.					
6. I think I learn more material in less time by working through programed material than I would by regular classroom presentation.					
7. I can concentrate better when working through programed material than in a regular classroom presentation.					
8. I often get discouraged when working through this programed material.					
9. Generally I find that when concepts are presented in the programed material, they are easier to understand than they would be in a typical classroom presentation.					
10. I can concentrate better during classroom presentations than during work on the programed material.					
11. I find working through programed units generally difficult.					

	strongly agree	agree	no opinion	diagree	strongly disagree
12. I enjoy programed material more than the lecture-discussion type presentations.					
13. When working through programed material, I generally get a feeling of accomplishment and confidence, because I can see right away when I understand the material.					
14. I feel that I would probably understand the material better if it would be presented to the class as a whole.					
15. I find working through the programed material easy.					
16. I feel that I would learn faster if the whole class would work through the material at the same time in a regular presentation.					

If you wish to make any comments or suggestions about the programed material, please feel free to do so.

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